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PAST AND PRESENT THEORIES OF ELECTRICITY.

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When the English court physician, William Gilbert, published, in 1600, his book on "Magnetic Bodies and the Lodestone," he included in it a chapter on the attraction of amber for light bodies. He writes: "Of this substance a few words must be said to show the nature of the attachment of bodies to it, and to point out the vast difference between this and the magnetic actions; for men still continue in ignorance and deem that inclination of bodies to amber to be an attraction and comparable to the magnetic coition." Gilbert was the first to break away from the scholastic methods of the middle ages. He says of the scholastic philosophy: "Such philosophy bears no fruit; for it rests simply on a few Greek or unusual terms—(used) just as our barbers toss a few Latin words in the hearing of the ignorant rabble in token of their learning and thus win reputation—(it) bears no fruit, because few of the philosophers themselves are investigators or have any first-hand acquaintance with things." Gilbert then narrates his experiments, showing that a great number of substances, as glass, sulphur, sealing wax, rock crystal and the precious stones, gain this property by friction. Such bodies he calls "electrics," and then he proceeds to seek the cause of this electrical attraction. We have thus here at the very beginning of electrical science three centuries ago the

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question which we are still asking today, "what is electricity?" and the search for the answer was thus early seen to demand "first-hand acquaintance with things." During these three hundred years our knowledge of electrical phenomena has grown far beyond any dream of Gilbert's generation, so that we now know that the attraction of amber is no isolated fact, and that the answer to the question "what is electricity?" would also tell us what light is, and perhaps what matter itself is. It is the purpose of this paper to trace briefly the lines of the development of our conceptions of electrical phenomena, and to note more particularly a few of the leading results of the admirable researches of the last six or seven years, especially in reference to past theories.

A study of the many theories and conceptions of electricity that have been advanced in these three centuries shows that four general views seem to represent the course of historical growth of our ideas of electricity. These may be named, the effluvium view, suggested in its first form by Gilbert; the fluid view, connected with the names of Franklin and Symner; the ether view, with which we associate the names of Faraday, Maxwell and Hertz; and the atomic or corpuscular view, which has been developed in the very recent years, largely by Prof. J. J. Thomson, and his pupils of the Cavendish Laboratory of Cambridge University.

The first of these theories requires but a few words here. Gilbert ascribed the electrical attraction to an effluvium exhaled by the bodies, and thought of the bodies as surrounded by an electrical atmosphere. It was this electrical atmosphere which acted on the bodies attracted. The effluvium theory under different forms persisted for a century and a half. Our present interest in it is principally as the theory preceding the time of Franklin.

During the years between Gilbert and Franklin from 1600 to about 1750, the scientific world was very busy experimenting with electricity. The division of bodies into electrical conductors and non-conductors had been discovered; the electric spark had been observed and felt; the fact of electrical repulsion as well as attraction had been noted; the two kinds of electrical states, vitreous and resinous, had thus been distinguished; and in 1745 the Dutch philosophers, Cunaeus and Mushenbrock, had discovered "the Leyden Phial," a discovery that produced the greatest sensation of the

day. It was just after this that Benjamin Franklin began his electrical experiments, probably incited to them largely by the popular interest in the Leyden jar. Franklin was at that time forty-one years old, the leading citizen of Philadelphia, and brought to these experiments his best energies. He writes on March 28, 1747, to Peter Collison, a member of the Royal Society of London, "For my own part, I never was before engaged in any study that so totally engrossed my attention and my time as this has lately done; for what with making experiments when I can be alone, and repeating them to my friends and acquaintances, who from the novelty of the thing come continually in crowds to see them, I have during some months past had little leisure for anything else." Franklin's active experimental work continued for about ten years and is recorded in his "Letters on Electricity," a classic work in electrical literature, and scarcely less fascinating reading than his famous "Autobiography." It is not the place here to take up Franklin's electrical work in detail. He is distinguished in the history of electricity as being the first to present in an acceptable form a complete theory of electricity. Even to this day it is in many respects the most noteworthy of electrical theories. At a single stroke Franklin's theory made possible a clear description of phenomena which before had been vague and involved. Franklin's theory was the famous single fluid theory of electricity. He assumed electricity to be a subtle matter or fluid. "In common matter," he says, "there is generally as much of the electrical (matter) as it will contain within its substance." If more is added, the body is said to be electrified positively; and when part of the natural proportion of electrical fluid is taken out, the body is electrified negatively. He then completes the theory by assuming an attraction between the common and electrical matter, and a repulsion between two quantities of electrical matter. With this theory Franklin explained as well as we can today the facts of electrical attraction and repulsion, of electrification by influence or induction, and the charging and discharging of the Leyden jar. Franklin was not the first to advance the idea of a fluid theory, but Franklin's clean-cut and original methods of experiment and statement gave the theory a form which secured its general acceptance, and hence the name Franklin's theory. And further, Franklin's

form of the fluid theory was not the only form that found acceptance. Many of the greatest investigators in electricity have preferred to look on the electric fluid as a two-part fluid. Robert Symner, an English contemporary and acquaintance of Franklin, was probably the first to suggest such a theory. He writes in the Philosophical Transactions for 1759 (Vol. XI, abridged edition): "When a body is said to be positively electrified, it is not simply that it is possessed of a larger share of electric matter than in the natural state; nor when it is said to be negatively electrified of a less; but that, in the former case, it is possessed of a larger portion of one of these active powers, and in the latter of a larger portion of the others; while a body in its natural state remains unelectrified from an equal balance of these two powers within it." Hence followed the two fluid statement of the fluid conception of electricity, the language of which has been more generally used in electrical literature than any other. We shall see in the latter part of this paper that Franklin's original statement is, however, nearer the truth.

After Franklin came a period of measurement and mathematical statement. Conlomb, in 1785, proved that the force between two electrical charges decreases as the squares of the distances between the charges increases; that is, that electrical forces follow the same laws as Newton's law for gravitational forces. The mathematical methods of the astronomer thus became immediately available, and a mathematical theory of electrostatics was brilliantly developed by such great writers as Laplace, Biot and Poisson. In fact, by 1820 electrostatics, to quote Prof. Rowland, "was very far advanced even as compared with our modern times." This application of gravitational mathematics had, however, added to or emphasized in the accepted fluid theory one most important idea. The electrical forces were assumed to act directly across space, like gravitational forces; they were assumed to be forces acting directly at a distance.

The next great name in the theory of electricity is that of Michael Faraday. Although born in humble surroundings and with none of the advantages of a university training, Faraday raised himself by his industry and genius to the highest rank in science. In 1820 he was a professor in the Royal Institution of

London, the successor of the great chemist, Sir Humphrey Davy. In that year Hans Christian Oersted published his splendid discovery of the magnetic action of the electric current of Galvani and Volta. This great discovery turned Faraday's mind to electrical experiments, but it was not until ten years later, in 1831, that Faraday's epoch-making "Experimental Researches" in electricity began to appear. The history of electricity from that time has the name of Faraday writ large on every page. He discovered electromagnetic induction and thus made possible the dynamo, the induction coil, and the alternating current transformer; he discovered the laws of electrolysis and laid the basis of the science of electrochemistry; he discovered the true action of insulators or dielectrics; while diamagnetism and the action of magnetic force on polarized light were first found by him. Great as Faraday's name is for these epoch-making discoveries, he is even more distinguished in science as the originator of a conception of the nature of electrical and magnetic forces, which has not only revolutionized the science of electricity and magnetism, but also the theory of light and radiant energy. Faraday had one of those rare independent minds which can free themselves from traditional opinions and can see things as they are. He was, as Hertz says, "a man who looked at phenomena with an open mind and without preconceived opinions, who started from what he saw, not from what he had heard, learned or read." And what did Faraday see? He saw two bodies drawn toward each other. What was the cause? Others had explained the attraction as due to something called electricity on the bodies. But electricity was something he could not perceive, so, instead of trying to explain something of which the very existence was hypothetical, he turned to investigate that which he could get at, that is the force between the bodies. Now the only way that Faraday could conceive of a force was as a push or a pull. To his mind the conception of a hypothetical agent acting at a distance afforded no explanation. So he turned to the space between the bodies to find the push or pull. Taking a little test body he could map out the direction of the force at each point in space, and thus could draw the lines of the force or "electric curves," as he at first called them. Further he proved that these electric curves or lines always joined to bodies which were being attracted to each other.

So he was led to his conception of lines of force. These lines of force became for him physical realities with just as actual an existence as elastic threads fastened on the two bodies and drawing them together. But how explain the existence of these lines? The answer was that they were lines of tension in a fluid medium, an ether. The idea of an ether was not new. Recently, Young and Fresnel had explained the most complicated phenomena of light by such an ether. Thus, Faraday satisfied his own mind and banished actions at a distance, substituting stresses and motions in the ether. But the point of view was so new and strange that it was long before others could follow. Undoubtedly Faraday's peculiar methods of statement had much to do with this. For Faraday was not a professed mathematician, although as Helmholtz says, "with quite a wonderful sagacity and intellectual precision Faraday performed in his brain the work of a great mathematician without using a single mathematical formula. He saw with his mind's eye that magnetized and dielectric bodies ought to have a tendency to contract in the direction of the lines of force and to dilate in all directions perpendicular to the former; that by these systems of tensions and pressures in the space which surrounds electrified bodies, magnets or wires conducting electric currents, all the phenomena of electro-static, magnetic electro-magnetic attraction, repulsion and induction could be explained without recurring at all to forces acting at a distance." As we follow the growth of these ideas in those wonderful "Experimental Researches" our admiration for the mind that could originate and formulate them is unmeasured.

But it is largely due to James Clerk Maxwell that the conceptions of Faraday were given that form and definiteness without which they would have failed to have affected science. Maxwell, unlike Faraday, was a trained mathematician. He had been an honor and prizeman in the most famous mathematical contest of the English universities. In electricity he had had no training except a close and profound study of Faraday's published work. He speaks, in his first memoir on this subject, of electricity as "a science in which I have hardly made a single experiment." He tells us in the introduction to his "Electricity and Magnetism," that his purpose was to translate Faraday's ideas into mathematical form, but he did more than translate, for Maxwell was one of the

rarest of creative geniuses Hertz says of the great paper which Maxwell read before the Royal Society in 1864: "It is impossible to study this wonderful theory without feeling as if the mathematical equations had an independent life and intelligence of their own; as if they were wiser than ourselves; indeed, wiser than their discoverer, as if they gave forth more than he put in them." The Faraday theory grew in Maxwell's hands, so that not only were the facts of electricity and magnetism given a formal dynamical explanation as stresses and motions in the ether, but it was shown that light was a periodic electro-magnetic action in this same ether. Maxwell's theory gained acceptance very slowly. At the time of Maxwell's death in 1879, "His supporters," says Prof. Glazebrook, "were limited to some few English-speaking pupils, young and enthusiastic, who were convinced, it may be in no small measure, by the affection and reverence with which they regarded their master." On the continent of Europe, the theory made almost no headway. Professor Boltzmann says that up to 1887, only two professors in the German-speaking universities mentioned Maxwell's theory in their lectures, Helmholtz in Berlin, and Stefan in Vienna, and they did not accept it. The theory was so different from all previous ideas that to most it seemed ingenious speculation rather than serious science. But in 1887 and 1888 there came a series of beautiful experiments which so completely verified Maxwell's fundamental conceptions that the whole world was almost instantly converted to the essential truth of the ideas of Faraday and Maxwell. These experiments were the electric wave experiments of Heinrich Hertz. What Hertz did was to produce periodic electric disturbances or waves and to show that these electric waves were propagated with a finite velocity, the velocity of light, and further that these electric waves were identical with the waves called light in all except wave lengths. The existence of the electro-magnetic ether was thus proven, and also the transmission of electric and magnetic forces through this ether.

After the striking confirmation of Maxwell's equations by Hertz's electric waves there came a period when many thought that there was no electricity, that what we had called electricity was simply a positive or negative displacement of the ether, showing itself at the boundary surfaces of conductors and insulators. Thus,

Dr. Oliver Lodge, in the introduction to his book on "Modern Views of Electricity," in 1889 says: "Few things in physical science appear to me more certain than what has so long been called electricity is a form or rather mode of manifestation of the ether. Such words as 'electrification' and 'electric' may remain; 'electricity' may gradually have to go. It can be noticed that whereas in the earlier part of the book the word 'electricity' occurs frequently and the word 'ether' seldom, in the latter portion this order of frequency is inverted." Still more emphatically wrote Prof. Rowland, in 1895. He wrote: "It is not uncommon for electricians to be asked whether modern science has yet determined the nature of electricity, and often find difficulty in answering the question. When the question comes from a person of small knowledge which we know to be of a vague and general character, we naturally answer it in an equally vague and general manner; but when it comes from a student of science anxious and able to bear the truth, we now answer with certainty that electricity no longer exists." These quotations indicate the ideas held by most of the ablest students ten years ago.

We now turn to the more recent theory of the nature of electricity, and it will be seen it involves also new views of the atom and of the nature of matter. We will first state briefly the theory and note a few of the reasons and results of it later. The theory may be summarized as follows: Every atom of ordinary matter has connected with it one or more smaller particles, called by Prof. J. J. Thomson corpuscles. These corpuscles are small, both in mass and size, as compared with the smallest atom. Compared with the hydrogen atom, the mass of a corpuscle is only as one to one thousand. Further, all corpuscles are of the same mass, whatever the kind of atom with which they are associated; that is, the corpuscles associated with oxygen are of the same mass and size as those with hydrogen, uranium or any other kind of matter. Each corpuscle is the bearer or carrier of a definite charge of resinous or negative electricity. As long as the corpuscle is joined to the atom, the atom is in a neutral electric state, but when the corpuscle is separated or dissociated from the atom, the atom is left charged positively, while the dissociated corpuscle is negatively

charged. That is, calling the two parts of the atom, ions, an atom is composed of two ions, a positive ion of a size and mass which depends on the kind of matter, and a negative ion of an invariable mass, about one thousandth the mass of the hydrogen atom. Then to charge a body positively, we remove the corpuscles or negative ions; to charge the body negatively, we add a surplus of corpuscles to it. A further property of the corpuscles is their penetrating power and great mobility. They can move through a metal and can when free be given velocities second only to that of light. An electric current is carried by these negatively charged corpuscles; that is, an electric current is simply a stream of these corpuscles with their negative charges. We have called the corpuscles the carriers of the charge, but some physicists think the corpuscles may be themselves the negative electricity. In conformity with that idea, they have been called electrons, a word suggested first by Dr. Johnstone Stoney, for the charge carried by an ion in electrolysis. Lord Kelvin uses the word electron for the same purpose. Prof. J. J. Thomson in his latest paper (March, 1903) returns to the term negative ion.

It seems hardly necessary to suggest that we are here back to the one fluid theory of Franklin, only the fluid has become atomic and its sign is changed. Two questions naturally come immediately to our lips: First, what are the reasons for advancing and holding this corpuscular or atomic theory? Next, how does it harmonize with the ether theory of Faraday and Maxwell?

To review the experiments and reasons which have led to this surprising and radical return to old ideas would be out of place in a paper of the length and character of this. It would involve an abstract of a literature which, while only six or seven years old, already numbers hundreds of papers and references as well as the explanation of new and involved methods of investigation. But a short statement of the range and principles of the researches may be made.

In the first place, it may be noted that these new concepts have come largely from a study of the passage of electricity through gases, and also from the application of the newer ideas of electrochemistry to gases. The line of research started with attempts to explain the discharge phenomena in the high vacuum tubes or

Crookes tubes. As is well known, in such tubes the negative electrode or cathode has streaming from it the peculiar cathode rays. Thomson found that these cathode rays were streams of extremely fine particles, the corpuscles of this new atomic theory. But the theory does not rest on a study of cathode rays alone. In 1896 Becquerel announced the important discovery of a new kind of radiation having many of the properties of the Roentgen rays. These rays are emitted by uranium, thorium, radium and probably by numbers of other substances. It has been shown that these radio-active substances are emitting these corpuscles. Further, Thomson and others have shown that metals illuminated by Roentgen rays or by ultra-violet light, and also incandescent metals give off the same corpuscles. All these cases, investigated by many persons with independent methods, have yielded the same results, so that the theory although new, already stands on a firm basis of experiment. In addition the atomic nature of electricity is not a new conception, nor one that has ceased at any time to be held by many thoughtful physicists. In the last volume of Helmholtz's papers in a lecture on Faraday's concepts, we find Helmholtz saying: "Now the most startling result of Faraday's law (of electrolysis) is perhaps this. If we accept the hypothesis that the elementary substances are composed of atoms, we cannot avoid concluding that electricity also, positive as well as negative, is divided into definite elementary portions, which behave like atoms of electricity." Helmholtz here refers to the quantity of electricity carried by an ion in electrolysis. The hydrogen ion for instance always carries $8x10^{-20}$ coulombs of electricity in any solution, and all other monad ions carry the same amount. Hence this quantity has been regarded as the natural unit of electricity, and called an "electron." It seems to be the smallest quantity of electricity that can exist in nature, and the laws of electrolysis indicate that all possible electric quantities are multiples of the electron. It is this same unit, the electron, that Thomson finds on the corpuscles. Possibly the corpuscle is the electron. If so, we are back to a material theory of electricity.

Certainly the new theory brings us much nearer to the nature of matter than anything ever reached before, and already scien-

tific literature is full of fascinating speculations on the part played by electrons in the activities of matter.

How does the new theory harmonize with the older theories? As already pointed out, it agrees with the single fluid theory, so that in the future we need not fight shy of the word electricity. With the ether theory, there are no doubt many difficulties to explain. The essential feature of the Faraday-Maxwell-Hertz conception of the ether has been proved beyond question. This essential is that there is an ether by which electric and magnetic forces are transmitted, so that the conception of force acting at a distance is banished; and, further, that this electro-magnetic ether is the same as the luminous ether, so that electric waves and light waves are the same, differing only as red light differs from blue light, in wave length. It was never an essential of the ether theory that the electric charge should be an ether phenomenon. In fact that was one feature of Maxwell's theory that was always vague. Thus Helmholtz wrote in 1881: "I confess I should really be at a loss to explain without the use of mathematical formulae what he (Maxwell) considers as a quantity of electricity. * * * It is not at all necessary to accept any definite opinion about the ultimate nature of the agent which we call electricity. Faraday himself avoided as much as possible giving any affirmative assertion regarding this problem, although he did not conceal his disinclination to believe in the existence of two opposite electric fluids." Perhaps we cannot better state the condition of the harmony of these theories than by a quotation from Prof. G. H. Bryan. He says: "The discovery of rays capable of discharging electrified bodies in air has not only shown the fallacy of our preconceived dogmatic notions as to the division of substances into conductors and dielectrics, but has taught us that the properties of the ether are not so simple as we had anticipated. We can only wonder whether Maxwell would have been able to develop his electro-magnetic and electro-optic theories had the complications arising from the Becquerel and other rays been before him; and the want now makes itself felt of a second Maxwell, who shall co-ordinate the newly-accumulated mass of experimental facts into the form of a connected mathematical theory."

ECONOMIC ZOÖLOGY.

BY FRANKLIN W. BARROWS.

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But there is another side, a brighter side, to the insect question. Dr. Howard says:

"Insects are beneficial: 1. As destroyers of injurious insects. 2. As destroyers of noxious plants. 3. As pollenizers of plants. 4. As scavengers. 5. As makers of soil. 6. As food (both for man and for poultry, song birds and food fishes) and as clothing, and as used in the arts."

It is needless to add that our Department of Agriculture, under the lead of such experts as the late Dr. Riley and Dr. Howard, whom I have just quoted, has spared no efforts to reap a profit from the insect world wherever possible. These men have raised the science of economic entomology to a position of international importance through their most gratifying success in destroying our injurious insects by importations of their enemies from foreign countries. Experiments in this line began as many as thirty years ago, but, as Howard says, these were all "dwarfed into insignificance by the astounding success of the importation of *Novius (Vedalia) cardinalis,* a ladybird beetle, from Australia into California in 1889." I will condense Howard's interesting account of this and similar importations.

The citrus crops of California were suffering from the ravages of the white or fluted scale, a very small insect which successfully resisted all measures employed against it, until it seemed that nothing could rescue the orange groves from certain destruction. At this juncture an *attaché* of the United States Division of Entomology visited Australia and succeeded in sending live beetles to California. Here they made themselves at home, multiplying with astonishing fecundity and attacking the scale insects so voraciously that within a few years they had literally exterminated them, and saved to the citrus industries of California, millions of dollars. Later, the United States entomologist had the pleasure of introducing the same beetle from California into South Africa, Egypt

and Portugal, in each of which localities it was successful in combating the white scale. Another ladybird beetle imported into California "has unquestionably ridden many olive groves of the destructive black scale, and is today present in many other orchards in such numbers that the scale practically makes no headway." Many other experiments of this sort are under way in this country, and the efficacy of insect importations has been successfully tested in Hawaii and other lands.

The last annual report of the United States Secretary of Agriculture announces the success of another importation, a most unique experiment, the scene of which lies in California. For several years the fruit growers had attempted to raise Smyrna figs in California, without success. About six years ago the Division of Entomology determined to introduce from the Mediterranean country a little insect, *Blastophaga grossorum,* which there performs the very essential function of pollenizing the fig. After four or five generations of this fertilizing insect had been reared at Fresno, it became evident that it would supply the only factor lacking for the successful growing of figs. And now the Smyrna figs of the Pacific Coast bid fair to take their rank along with the standard figs of commerce. The United States entomologist is prepared to furnish colonies of these precious insects to all intending fig growers.

In the few instances just described we behold the realization of one of the chief ideals of economic biology—the subjection of useful species to the will of man.

Many insects might be named which are of great value in agriculture and commerce. We think at once of the silk-worm, which, as Professor Shaler remarks, is of more importance to us than the elephant, because it supports an industry out of which ten millions of human beings get their living. The bee is busy all over the earth, furnishing annually ten thousand tons of honey besides a valuable output of wax. The cochineal bug of the tropics, from which we derive our supply of carmine, once outranked all other insects in the commercial value of its product. Now, however, the aniline colors have largely superseded carmine.

Lest this paper should become merely a catalogue, we will spare you the repetition of a score or more of useful insects, merely

remarking that, possibly this class of animals comprises among its millions of species more friends than foes.

The birds undoubtedly rank next to the insects in economic importance. Nearly all of them are useful to man. A recent writer says that if all our native birds were to be destroyed man would die of starvation inside of ten years; mainly because of the unchecked increase of the insects that destroy our food plants. However this may be, we know that civilization is coming to a realizing sense of its dependance on birds in the war against noxious animals and weeds. This rational attitude toward our birds is due largely to the careful investigations of bird habits in every country of the first rank, particularly in our own land. The study of the relation of birds to agriculture has been very thoroughly cultivated by the United States Department of Agriculture, involving, among other methods, the investigation of the contents of about 20,000 birds' stomachs, and the careful tabulation of the articles of diet. The report published in 1899 states that only six or eight of our native American birds are found to be injurious to man. The English sparrow and a few hawks and owls are condemned to extermination by this verdict of the department, while, on the other hand, some species formerly considered noxious are found to be decidedly useful. Everybody knows something about the campaign against the use of birds for millinery, and the measure of support that it has received. Our government and the various states are slowly modifying their legislation and coming to a more rational way of dealing with this question. Hereafter questions involving the welfare of any of our birds are likely to be referred to experts and not left entirely to the whims of the selfish or the tender mercies of the careless.

Of the higher animals, the mammals, there are scores of species whose value is well known. We need merely to mention the fur-bearing beasts, and our game animals to recall many species to mind. Of these, one and all, we confess in truth that we have sinned against them, and are reaping the results of our folly in a threatened extermination of some of the most valuable. The law makers are proverbially slow in acting where the fate of wild animals is concerned, as is too well seen in the case of the fur seal, the buffalo, and many kinds of wild game. Public opinion, how-

ever, is becoming stronger and with the help and backing of such organizations as the League of American Sportsmen it is likely to create gradually better conditions for all the animals that are hunted. The passing of the fur animals of the north has given a market value to such inferior pelts as those of cats, squirrels, rabbits and rats. The breeding of the Arctic fox promises to become a very productive industry in Alaska. As for leather, there seems to be no sort of hide from which it is not prepared today, from the skin of the eel to that of the elephant.

The discussion of our topic would be incomplete without mention of some of the blunders that man has made in his efforts to make himself master of the situation. The greatest of these, is the oft repeated sin of extermination. Something like a score of species were exterminated by man's misdirected industry during the nineteenth century, and many other species were so hard pressed that their disappearance from earth seems a question of a few years.

Another mistake that man has repeated often with disastrous results is the disturbance of the balance of nature by the introduction of wild animals from one country to another. The case of the mongoose in Jamaica is a good illustration, and so well known that it needs but a word of explanation. This mammal was brought from India to rid Jamaica of its pest of rats. Being free from its natural enemies, against which it had always competed in India, it soon became more of a nuisance than the rats that it had supplanted—in fact it completely upset the balance of nature, until the government of the island offered a bounty on its head. In spite of this unsavory chapter of natural history, it has required the most vigilant and determined opposition on the part of the United States government to prevent the importation of the mongoose by certain well meaning people, to the southern states and to Hawaii. Australia has suffered the loss of millions of dollars by the introduction of rabbits from England, merely to furnish game for hunting. The English sparrow came to America, by invitation, in 1850. We all know the result. The gypsy moth was turned loose in Massachusetts in 1868 or '69, by an innocent experimenter who wished to test its silk making powers. In twenty years the state government began the task of exterminating the moth, and now, after expending several millions of dollars, it finds

the moth slightly ahead in the race. It is not strange that some of our scientific experts are trying to secure legislation that shall make it a criminal offense to bring into the country any foreign animal without the consent of some regularly constituted authority.

The future of economic zoölogy is filled with marvellous possibilities, and bright with promise. Applied zoölogy has taken its place among the arts and sciences of this progressive age and it has its skilled experts, its laboratories, its problems, and its solution of some of the vexatious questions of the day. Every fish hatchery, every experimental station, every agricultural college, and in a growing degree, every biological laboratory in the world, is a center for the prosecution of research and experiment in this vast field. Every discovery in biology, however impractical and trivial it may at first appear, conduces to some new triumph of man over the plastic forces of the animate world. Let us now consider a few of the lines along which the future achievements of this science are likely to be worked out.

1. We shall put a stop to the ruthless slaughter of our wild animals wherever a civilized government has its "sphere of influence." We are likely to go still further in this direction and to set aside parts of the national domain as permanent parks in which every form of life shall be absolutely safe from man's marauding hand. Our own government has made a good beginning in the Yellowstone National Park. It remains now to secure tracts of available wilderness east of the Mississippi, and on the Pacific Coast. These reservations may be made valuable as forestry preserves, thus serving for all time a double purpose. Some of our states have made beginnings in this work, but we need more extensive reservations under federal control. The movement recently sanctioned by Mr. Hornaday, of New York city—the setting apart of a magnificent national reserve in southern Alaska, should be consummated without delay. We shall then have a place of refuge for the most superb mammals of the continent—the buffalo, musk ox, various species of bear, the beaver, many of the choicest furbearing animals, etc. It is a wise provision of Providence that has placed the noblest fauna of North America in our own domain and in a part of it that offers few temptations to the farmer or the miner. We shall certainly be very remiss if we fail to set apart and

patrol this last refuge of the animals that are now hunted to the death.

Other countries are moving in this matter; even in Africa the protection of wild animals is to be undertaken by the powers. A convention signed by all the leading governments of Europe about three years ago, makes rigid restrictions on the hunting of game in Africa, and among other agreements, binds the signatory powers to encourage the domestication of the zebra, elephant, ostrich, etc., to prevent the transmission of diseases from tame to wild animals, to destroy the eggs of crocodiles, poisonous snakes, pythons, and in many other ways to render service to the useful or harmless animals that are in greater danger of extermination.

2. The most inviting service that awaits the energies of the economic zoölogist is the seeking out of new species of animals that shall be made useful to man in some new way. The number of animals that we utilize at present is surprisingly small. The total of animal species classified and named by our scholars was estimated at over 71,000 in the year 1830; 50 years later, in 1881, there were over 311,000; while in 1896 there were said to be 366,000 species of animals having scientific names and recorded in the books. It is popularly believed that Adam finished the business of naming the animals before he left his residence in Eden, but we see from the figures just quoted that our own contemporaries found and named in the last three-quarters of the nineteenth century nearly 300,000 that Adam in his hurry had overlooked. And lest any one should think that the task was completed by the dawn of the twentieth century, we are told that the sum total of animal species is probably no less than ten millions. Indeed, Dr. Riley, once U. S. entomologist, estimated the varieties of insects alone at ten millions, which would bring up the sum of all animal species to fifteen millions. There remain, therefore, between nine million and fourteen million species still nameless—enough to furnish occupation for a long time to those who like that sort of thing. The real question, the main question now, is, What is the place of these species in the economy of nature? Is it injurious to the interests of man? If not, can we turn it to account in any way? The number of animals utilized by man is small, ridiculously small, it would seem. Shaler says that we use only 100 animals and 1,000

plants out of millions of species. Only twelve insects, he tells us, are used directly by man, and only two of these, the bee and the silk worm, can be called domesticated. America, the scene of so many of the latest triumphs of economic zoölogy, has added only one animal "of definite use to man over a wide field," to the list of domestic animals; and that is the turkey, which, by the way, became domesticated in Europe and was brought back again to its old home. These are the statements made by Shaler. It is true that we are now domesticating the buffalo, but with rather doubtful success. Peter Kalm, who visited this country in 1750, speaks of seeing domestic buffalo here. The early settlers of this country had their schemes for domesticating the moose, but they never accomplished the work. Other continents, also, have their unimproved opportunities. In Africa the breeding of zebroids, crosses between horses and the native zebras, promises to revolutionize the horse question. The bare possibility of originating on African soil a hybrid that shall compete successfully with the imported American mule, sheds great hope on the life of a South African, whatever his politics may be. So, indeed, the discovery of a single useful species, or the finding of a new use for an already serviceable animal, may be the means of adding millions to the revenues of a nation. No country can consider the exploitation of its animal resources completed until it has thus pressed the last recruit into its services and developed it to its highest capacity.

3. This brings us to the last and highest ideal to be sought in our use and treatment of animals, namely, the development of a stronger sympathy between us and our dumb friends by educating not only them but ourselves as well. Professor Shaler, in his convincing way, shows us that the animals most companionable with man have developed human qualities of mind by long processes of artificial selection. This is illustrated in what we all recognize as a well-bred dog; and who of us does not recognize a well-bred dog as instinctively as a well-bred man? That the domestic animal should become assimilated, in mental traits, to its lord and master is as fortunate as it is natural, for it opens up to us immense possibilities. If in the future as much attention shall be given to the improvement of animals in this line as in the past we have bestowed on the development of certain

physical "points" in every breed of dogs or horses or pigeons, we may expect to bring our animals into more helpful and affectionate relationships with us than ever before. Indeed, such a result is inevitable as surely as it is ever attempted by the scientific breeder. If you find your dog companionable in your romps through the country or in the quieter hours that you spend at the fireside, why shall not his descendants in future ages be still more worthy to associate on terms of intimacy with the very best families? Have we ever thought of the possible social status of some of our dumb friends, a few centuries hence?

They say that "slumming" has a most wholesome influence on the social missionary. By a sort of natural reciprocity he receives from his lowly environment as much as he gives, and so he develops a fine personality while sacrificing himself for others. It is equally true that if we adopt the honest and human attitude toward the animals, using them for our convenience, if we choose, but treating them always with the consideration due to every fellow creature, we shall minister to the development of our own characters. This high philosophy is not inconsistent with the proper use of animals in any kind of service, nor does it prevent the destroying of those forms that torment ourselves or our animal friends. In some countries, as, for example, India, many forms of animals are deified, housed in temples, worshiped, and regarded with such awe that no one dares to kill one of them even to put it out of extreme misery. Yet our own people are much more humane than these worshipers of animals, and without any of their befogging and heathenish philosophy. As we extend our power over the animals it will ever be with a growing sense of respect for their myriad forms, and a corresponding sense of our own responsibility to their Creator and ours for the way in which we exercise our undivided dominion.

SYMPOSIUM ON THE TEACHING OF PHYSICAL CHEMISTRY TO BEGINNING STUDENTS.

Early in February of the present year a circular letter was sent by the president of the Chemistry Teachers' Club to a number of professors and teachers of chemistry, asking for their views upon the following questions:

1. Should physical chemistry be considered at all in the first year of the teaching of chemistry?

2. If so, to what extent and in what way?

3. What is the minimum of knowledge of physical chemistry which the teacher of elementary chemistry should possess?

4. How can those teachers whose course of preparation for their work has not included modern physical chemistry best equip themselves for the consideration which they should give to it in their teaching?

It was explained in the letter that these questions were to be discussed at a meeting of the Chemistry Teachers' Club to be held in New York City the first week in March, and that the object in sending out the circular letter was to obtain for that occasion a more complete symposium of views upon the questions for the benefit of the members of the Club. With one or two exceptions, replies to these questions were received from all those to whom the circular letter was sent. These replies were read at the meeting, and were so gratifying in their discussion of the questions from various points of view, that the Club voted to ask from the authors of the letters permission to print them for wider circulation. This permission was granted in every instance and the letters are accordingly presented herewith to the readers of SCHOOL SCIENCE.

From Professor JOSEPH W. RICHARDS, Lehigh University, Bethlehem, Pa.:

"1. I think the first year of the teaching of chemistry should contain but brief allusion to the facts of physical chemistry, and none at all to its theories.

"2. I think the extent to which it should be introduced in the beginning should be almost exclusively in the direction of thermo-chemistry, *i. e.,* giving the students tables of the heat of formation of the simpler chemical compounds, teaching them what these mean, and having them write the *energy equation* of every reaction which they perform. You will thus lay a firm foundation for the idea of the chemical energy involved in chemical reactions, and go far towards taking away the empirical nature of chemistry as now taught, and putting in its place a rational view of chemical reactions as being caused by the running down of chemical energy. I know by experience that this is the *esoteric* view of chemistry, which unlocks almost all its secrets, and is a point of view lamentably neglected in our ordinary chemistry classes. When we come later to connect chemistry with thermal, mechanical or electrical energy, we build almost exclusively upon this foundation of *chemical energy,* and it is the only foundation which gives chemistry a rank among the exact sciences and removes from it the reproach of simple empiricism.

"3. The teacher of elementary chemistry should possess a working knowledge of thermo-chemical data and principles. I know of no book so stimulating or instructive in this respect as Ditte's 'Traité Elementaire de Chimie fondée sur la Thermo-Chimie.' It is in easy French, and I recommend every teacher to read it and copy its methods. I wish we had an elementary treatise like it in English.

"I do not think it necessary, or even *advisable,* that the teacher should be well acquainted with the theories of modern physical chemistry. A knowledge of some of the more common *facts* will amply suffice, and then let the student content himself with being told these *facts,* if he asks any questions.

"4. I have already put my finger on what I consider the weak spot in our elementary chemical training, the lack—almost total absence—of the *energy standpoint.* I believe, in fact, I know from experience, that it can be taught from the very beginning, and is the most stimulating information which the beginner can possess. He feels that he has the 'multiplication table of chemistry' in his hands to work with, when he has a list of heats of formation.

"If the teacher reads French, let him read Ditte. If not, let him read the chapters in thermo-chemistry in Smith's-Richter Inorganic Chemistry, and get the energy equation for every chemical equation given the student. It is as important for him to learn this *ab initio* as to learn the *weight* relations and the volume relation. (The latter are often lamentably neglected.)

"P. S. In this connection, impress on your Club that if weights are taken in *grammes,* every molecular weight of a gas represents 22.22 litres; if weights are kilos, every molecular weight represents 22.22 m^3; and if weights are *ounces* (Av.) every molecular weight represents 22.22 *cubic feet; e. g.,* 28 grammes CO = 22.22 litres; 28 oz. CO = 22.22

feet.[3] This last is an accidental relation, which I discovered, and is of the highest usefulness, when applying chemistry to laboratory and industrial calculations in general, for tranposing English to metric measures and *vice versa.*"

From Professor EDWARD HART, Lafayette College, Easton, Pa.:

"1. On the subject of which you speak I do not know whether I can answer in the order of your queries exactly. I may say first that I think all sorts of chemistry should be considered in the first year's teaching of chemistry, and under this I would include elementary physical chemistry as well as other things.

"2. To the second query, my own notion would be not to take it up to any large extent as a separate subject or separate part of the subject, but it is quite easy under electrolysis, to define what is meant by an ion, and how they are supposed to act toward the electrical charge. I think the subject of electrolysis cannot very well be understood without this. When water of crystallization is spoken of, the question of temperature and of mass can readily be explained. I think you will readily catch my idea as to its application in other connections.

"3. I think it unnecessary for those who are to teach elementary chemistry only to have much mathematical knowledge of the subject. Of course this is desirable, but it does not seem to me essential.

"4. I do not know of any better way than to read such books as Jones' 'Physical Chemistry,' with the necessary elementary knowledge which a teacher in chemistry may already be supposed to have. I think that this would be a good book to start with. This could, of course, be followed up by the study of Nernst's book. Perhaps a better plan would be to read carefully Ostwald's recent treatise on 'The Principles of Inorganic Chemistry.' An elementary view of the subject entirely free from the mathematical demonstration which Nernst gives can be found there presented in very attractive form. I have found Ostwald's book very suggestive and I presume most chemists are benefited by reading it."

From Professor H. L. WELLS, Yale University, New Haven, Conn.:

"1. It seems to me that there is but little in the domain now called physical chemistry that is appropriate for use in the first year of teaching chemistry, particularly with younger pupils.

"2. If any is introduced it need not be called physical chemistry, for it is really an extension of the older theoretical part of chemistry. I think it would be well to give some idea of ions, since this helps greatly in the understanding of the chemical reactions, particularly neutralization and precipitation. I think also that in connection with the study of the gas-laws, the fact should be brought forward that these laws apply to solutions. Beyond the two things that have been mentioned it would seem to me unnecessary to go with beginners.

"3. Enough to understand well the things mentioned in '2', and to explain the reasons for accepting the views presented; *e. g.*, the significance of osmotic pressure in liquids, of the conductivity of electrolytes in solution, and a few other fundamental things about solutions.

"4. A little careful reading should equip the teacher sufficiently for this purpose. Perhaps H. C. Jones' 'Elements of Physical Chemistry' is the best book available, if the proper parts are selected for reading."

From Professor WILDER D. BANCROFT, Cornell University, Ithaca, N. Y.:

"I do not believe in introducing any more physical chemistry into the first year than the little qualitative physical chemistry that they now get in most places. The student should learn that boiling-points and freezing-points change with pressure and concentration; that a substance has a definite solubility at a definite temperature; that the dissociation of calcium carbonate is a function of pressure and temperature. They should also learn about sublimation pressures and about qualitative mass-action. They get all this after a fashion now, and I should like to see it put more briefly and more intelligently. There is no minimum knowledge of physical chemistry which the teacher of elementary chemistry should have. He will always know too little. It is one thing to leave out the physical chemistry very largely from the first year because it does not belong there, and quite another thing to leave it out because the teacher does not know it exists.

"I am not very sanguine as to the results of home study in physical chemistry. You can get facts that way; but facts are apt to be so much dead weight. A training in physical chemistry is a training in thinking. I find no difficulty in teaching my students facts, but I have great difficulty in teaching them to swing their facts. If the people insist on reading, I suppose that Walker's 'Introduction to Physical Chemistry' and Lüpke's 'Elements of Electrochemistry' will do them very little harm."

From Professor CHARLES E. MUNROE, Columbian University, Washington, D. C.:

"Replying to your favor of February 23, I have to state that I believe that 'Physical Chemistry' *as such* should not be considered in the first year of the teaching of chemistry. Yet the teacher should so treat of the topics called for in Document No. 8 of the College Entrance Board—Chemistry—that the student will get the most modern view. This knowledge the teacher can acquire from such books as 'Elements of Physical Chemistry' by H. C. Jones and 'General Principles of Physical Science' by Arthur A. Noyes."

From Professor LEVERETT MEARS, Williams College, Williamstown, Mass.:

"The questions you propound are easy to ask but difficult to answer. Concerning the first two, I would say that teachers of elementary chem-

istry in secondary schools ought not to undertake to teach *all* of theoretical chemistry, but, in so far as the subject is taken up, nothing should be taught that is to be unlearned by the pupil in after years. In connection with the electrolysis of copper sulphate and acidulated water, for instance, the ion theory should be mentioned if *any* explanation is attempted. The periodic system might be alluded to, but no attempt made to study its *details*.

"As regards the last two questions, much would depend on the previous training of the teacher. The study of a good treatise on physical chemistry or a course at a summer school might suffice in the case of a person well grounded in general and analytical chemistry and physics. In the case of a person who, by circumstances, has been obliged to teach elementary chemistry *without* such previous training, I would say, let physical chemistry alone.

"My own view of teaching elementary chemistry in secondary schools is that *only those* who have had thorough and comprehensive courses in general and theoretical chemistry, including organic, together with qualitative and quantitative analysis, are fitted to teach even the elementary portion of the subject as it should be taught. Such teachers undoubtedly would be prepared to make a judicious use of *some* of the material offered by the recent developments in physical chemistry."

From Professor Clarence L. Speyers, Rutgers College, New Brunswick, N. J.:

"Defining physical chemistry as the department of chemistry that uses physical means in the investigation of chemical phenomena, I do not see how this subject can be profitably taught until towards the end of a chemical course, just about before the student commences investigation, I should say.

"It seems to me that the student should be acquainted with very many chemical phenomena before the complicated laws expressing the reactions can be properly understood. A very substantial knowledge of physics is also needed, which would delay the consideration of other departments of chemistry until late in the course of studies, far later than, in my opinion, it should be. Consequently I am averse to bringing in physical chemistry until late in the study of chemistry; not at all in the school course, late in the college course.

"To the teacher of elementary chemistry, I would say: Know at least as much as is found in Morgan's 'Elements of Physical Chemistry,' paying particular attention to the problems. It will give you a survey of the whole field that will enable you to explain to your pupils many things not found in elementary text-books of chemistry for beginners. You can equip yourself very well by private study of the above book, aided by such experiments as you can find opportunity for, following the directions given in the last German edition of Ostwald's 'Physico-Chemical Experiments.'"

From Mr. R. P. WILLIAMS, English High School, Boston, Mass.:

"I shall have to answer only one of your questions regarding physical chemistry. Obviously then, the answer is in the negative.

"Unless there is much more than the usual time allotted to high school chemistry, any extended reference even to the subject must be at the expense of other more important topics. *Reason No. 1.*

"Until a sufficient number of facts have been accumulated to entirely supersede the theories of solution, etc., given in all text-books; enough to base a theory upon which will, from the very outset of chemical study, satisfy the facts, it is confusing to the pupil who is a beginner. If at the very first you are willing to talk about solutions as containing sodium ions and chlorine ions, and not as having sodium chloride, and stick to it for all cases from the first lesson in chemistry, it may do to introduce it—not otherwise. Even then confusion arises in the mind of the beginner that salts have ions and sugars not, etc. *Reason No. 2.*

"Elementary chemical treatises have not arrived at the stage when the subject can be exclusively used from the beginning. Even the foremost advocates—some of them, at least—do not recommend physical chemistry before the study of qualitative analysis. As a matter of fact, certain prominent technological schools take physical chemistry in the third or fourth year of their course. It seems, therefore, rather previous for high schools to take up the subject by anything more than allusion to, or brief description of, ionic and other physical theories. *Reason No. 3.*"

From Professor T. W. RICHARDS, Harvard University, Cambridge, Mass.:

"In the first place I think that everyone should pursue an elementary course on physics before studying chemistry. Let me now answer your questions.

"1. Yes.

"2. It seems to me that atom and molecule cannot be defined without the hypothesis of Avogadro and the rule of Dulong and Petit, hence these should be taught if the useful atomic hypothesis is to be discussed. In the next place it seems to me highly important to emphasize the energetic side of chemistry. We value coal primarily as a source of energy, and not as a means of making carbon dioxide; and yet the great heat of combustion of carbon, and the method of storing this potential energy in the coal, are rarely even mentioned in an elementary course on chemistry—much less emphasized. The fundamental principle of equilibrium, that when any reacting substance is added to a mixture already in equilibrium the tendency is to absorb or use up some of the substance added, is also important. Concerning the hypothesis of electrolytic dissociation, it is expedient to point out that there is no reason for believing that all of a salt exists as such in solution, but rather many reasons for believing that it does not.

"Throughout the course the greatest pains should be taken to distinguish between *facts* and hypotheses or *guesses*. In every case the facts should be given first, and the possible explanations afterwards.

"3. Enough to understand the above principles and to follow intelligently such a course as that outlined in the Harvard 'Requirements.'

"4. I think that a teacher who has not previously studied physical chemistry might acquire the above knowledge by studying any of the more elementary among the modern text-books upon physical chemistry, for example, Walker's 'Introduction.'

"The most important thing of all is to make the pupils *think*. Isolated facts will always be forgotten in a few years, and abstract theories, too, will not be permanent property; but if the relations of facts to one another and to the theories are properly developed in the pupil's mind, he will have attained exercise in thinking power which will permanently develop his brain."

From Dr. Arthur A. Noyes, Massachusetts Institute of Technology, Boston, Mass.:

"The questions which you raise in regard to the relation of physical chemistry to elementary instruction in chemistry can not be satisfactorily answered in a few words. My opinion in regard to the matter may, however, be summed up in the statement that, while it is desirable that much of the modern physical chemistry be introduced into such instruction, and while it will undoubtedly ultimately be so introduced, the difficulties in the way of its immediate introduction, at any rate at all generally, are very serious. For its successful incorporation with elementary instruction, three conditions must be fulfilled.

"1st. There must be a good elementary text-book presenting the subject in a scientific but elementary manner.

"2nd. Time must be available for drilling the pupils in this new part of the subject.

"3rd. The teachers must have a greater knowledge of modern physical chemistry than many of them now possess.

"I mention the text-book first of all; for, until this is available, I do not think it is of any use to attempt the general introduction of physical chemistry into elementary teaching; though it might, of course, be possible for individual teachers who have special opportunities for study to do so. Such a text-book must be written by a person who is, on the one hand, thoroughly familiar with the principles and applications of physical chemistry and has a proper sense of proportion and perspective with reference to them, and who, on the other hand, appreciates the mental attitude of a youth of fifteen and has the power of presenting the subject in a clear manner and in close connection with specific facts.

The question of time is a very important matter, also. While I do not hold the opinion that many of the important physio-chemical prin-

ciples are beyond the capabilities of the average pupil in the higher classes of the secondary schools, I do think that a large amount of drilling upon them will be necessary. The mere statement of the existence of certain principles and theories is not only of no value whatever, but even objectionable. For example, no teacher should attempt to teach the Mass-Action Law or Ionic Theory, unless it is intended to make abundant application of that law and that theory throughout the descriptive part of the subject. Moreover, the main defect in science teaching of all kinds is that too much emphasis is laid on the imparting of knowledge and too little on the mental training which science, properly taught, ought to give; and it would be a distinct misfortune if the attempt to introduce physical chemistry had the effect of increasing the material which the student had to learn at a sacrifice of the time which should be devoted to drilling him in close observation, correct inference, and clear thinking. One of the strongest reasons for the introduction of physical chemistry into elementary work is, to be sure, the fact that it furnishes a much better opportunity for mental drill than does the older descriptive chemistry, but a considerable amount of time is necessary in order to make this effective.

"The third point named, the proficiency of the teacher in the subject, is also essential, especially so long as no thoroughly satisfactory text-book has been written. The applications of the Ionic Theory and the Mass-Action Law are by no means simple in many cases, and a teacher not proficient in those subjects would be apt often to lead his students astray. The best method for teachers to acquire this necessary information would seem to be to read such works as Findlay's translation of Ostwald's 'Inorganic Chemistry,' and, if practicable, to take advanced summer courses at the leading universities in physical chemistry, laboratory experimenting being included if possible.

"Since these conditions cannot by any means be fulfilled at present, it seems to me it would be a great mistake to take any action which would *force* secondary school teachers of chemistry into the teaching of physical chemistry; such action, for example, as placing questions upon that subject on the college examination papers. All that can be done at present would seem to be to urge the secondary school teachers to make themselves familiar as rapidly as possible with the modern principles of physical chemistry, with the idea that they might then use their judgment in teaching them to their students, especially to the brighter ones among them.

"I hope that these preceding statements will serve to give you a good idea of my position, which is that, while physical chemistry should ultimately form an important part of elementary chemistry teaching, it is not wise to introduce it precipitately or by coercive means, and that the conditions are not such as would make possible at present its general introduction."

From Professor WILLIAM A. NOYES, Rose Polytechnic Institute, Terre Haute, Ind.:

"In reply to your questions I would say: First, the term 'physical chemistry' in its real meaning includes a study of the physical properties of gases, the specific heats of elements, and many other topics of this kind which should always be considered in teaching elementary chemistry. In a narrower sense, physical chemistry is taken as synonymous with the modern theory of solution, the study of mass action and similar phenomena. In this sense, also, I think the first year of chemistry should include a considerable amount of physical chemistry, especially demonstrations by the teacher or pupil, or both, of transference of ions under the influence of an electric current; the strength of acids as shown, for example, by the conduct of a solution containing potassium iodide and potassium bromate toward normal solutions of hydrochloric, oxalic and acetic acids; the phenomena of mass action as illustrated, for example, by the conduct of cadmium toward hydrogen sulphide in the presence of dilute or stronger acids; a discussion of 'complete' reactions as dependent upon volatility, insolubility or non-dissociation of one of the products. All of these matters should be presented in a simple, non-mathematical manner, and will, if so presented, very greatly facilitate the acquirement of the knowledge of chemical phenomena. This answers your first and second questions.

"As to the third, I believe that no one should attempt to teach chemistry who has not followed the subject for at least two years under good instruction, taking, say, two lectures or recitations a week and ten hours a week of laboratory work at least for that period of time. Such a course as this would naturally include a pretty thorough study of general chemistry and some study of qualitative and quantitative analysis, and probably some work in inorganic preparations. Some knowledge of organic chemistry would also be very desirable.

"Among the books which are to be found the most useful for teachers who have not studied modern physical chemistry may be mentioned: 'General Principles of Physical Science,' by A. A. Noyes, published by Henry Holt & Co.; 'Physical Chemistry,' by Jas. Walker, published by the Macmillan Co.; also, 'Physical Chemistry,' by H. C. Jones, published by the same company. All teachers should read very carefully Professor Alexander Smith's and L. B. Hall's 'Teaching of Chemistry and Physics,' published by Longmans, Green & Co. Professor Alexander Smith's 'Laboratory Outlines of General Chemistry,' published by the University of Chicago Press, will also be found very useful; also the articles by A. A. Noyes, on 'Lecture Experiments on Physical Chemistry,' which have been published in the *Journal of the American Chemical Society.*"

From Professor ALEXANDER SMITH, University of Chicago, Chicago:

"1. As to whether physical chemistry should be considered at all in the first year of the teaching of chemistry: The term physical chemistry is rather terrifying, and if it means a *theoretical* treatment of questions connected with thermo-chemistry, electro-chemistry, chemical equilibrium, or phenomena of solutions, I should say *not*, most emphatically. It is evident, however, that the physico-chemical investigations of the last few years have enabled us to adopt a correct attitude toward some familiar questions, and that the conclusions should certainly be allowed to reach the beginner in chemistry so far as he comes into contact with anything upon which they bear. The least that can be done with it is that the teacher should have the modern views prominently in mind during his teaching, whether he discusses them specifically or not. Modern treatment of every branch of chemistry—inorganic, organic and analytical—involves the influence of the background of physico-chemical work, even where formal physical chemistry does not actively intervene.

"For example, the modern electromotive series of the elements can be referred to dozens of times in the course of the most elementary work, with great advantage. It illustrates the activity of the elements, the stability of their compounds, the reducibility of their oxides, their power of displacing each other from combination, their tendency to occur free in nature or the reverse, and many other things, besides the difference of potential which we get when they are arranged so as to form a battery. Again, electrical processes are now so much in use in chemical industries that the obligation laid upon the teacher to maintain contact with everyday matters, compels him to put more stress on electrolysis than was formerly necessary. Finally, ideas connected with chemical equilibrium are so important in the explanation of some of the commonest interactions, that it seems to me some elementary conceptions connected with it must find their way into secondary school teaching, whether the teacher is conscious of it or not.

"2. I see that I have already answered this question ('How much?') in part. I should say further, however, that there is not time for more than an occasional application of physico-chemical conceptions. The beginner has far too much to learn about the physical properties of substances and the chemical interpretation of the physical phenomena which are the medium through which chemical change is observed, to be able to devote much time to anything else. If it were a question of memorizing a lot of facts, then physical chemistry might displace some facts of descriptive chemistry formerly given. The question, however, is that of conferring a certain degree of technical skill in the details of observation and inference which are under all circumstances the fundamental core of chemical work.

"In regard to the way in which physico-chemical ideas should be taught, I think it should be always by experimental demonstration or in connection with the discussion of experiments performed by students in

the laboratory. Theoretical matters should never be taught for their own sake, but only when, and in so far as, they can assist in coördinating facts of observation and rationalizing them. For example, if we are showing the decomposition of an aqueous solution of potassium chloride by means of the electric current, an operation which plays an important part in some industries, we have to show how the material in the middle of the solution is influenced by the current and reaches the electrodes. Experiments showing the drifting of the materials in solution under the influence of the current (described in terms of the theory as 'migration of the ions,' but existing whether ions are accepted or not) may be appropriately shown.

"3. I do not know how to describe the minimum knowledge of physical chemistry which the teacher should possess. It is not necessary that he should be familiar with thermo-dynamical demonstrations of theoretical points. It is, however, essential that he should be thoroughly familiar with experimental means of illustrating the various theories and should be in possession of a sound knowledge of the modern views in regard to everything in general chemistry which has been touched by the physical chemist. He should, for instance, know that catalytic agents affect the speed of chemical actions, but do not bring about actions which cannot otherwise take place. He should understand that the liberation of water of crystallization from a salt is not, under ordinary conditions, so much a question of definite temperatures, as the statements in most of the books suggest, but a question of definite pressures of water vapor. In other words, it is not a profound knowledge of highly recondite branches of the subject that he needs, but thorough familiarity with the theories and how to expound and illustrate them, the facts and how to correlate, explain and interpret them, and sufficient imagination to enable him to present vividly in many lights precisely the conception which he wishes to convey.

"4. The teacher whose preparation has not included modern views in regard to chemistry should read *all* the treatises on physical chemistry, paying particular attention to the concrete illustrations which they contain. He should himself perform the various experiments for illustrating principles of physical chemistry which have been so ingeniously contrived by A. A. Noyes, Lash Miller, Muir and Carnegie and others. The references to these experiments may be familiar to most teachers of chemistry. They are given in the book referred to at the opening of my letter. This much is within the power of every teacher.

"At the same time, in almost all cases, much time and effort would be saved and much better results attained if the teacher could observe the teaching of elementary chemistry by those who use the modern conceptions. This may be done by attending the summer schools established by a number of our universities. I have not examined the summer circulars to see how far the opportunity is offered for observation of this

kind of teaching in all of them. I presume, however, that, like the University of Chicago, they all offer an elementary course in chemistry which is as modern as they know how to make it, and that most of them give opportunities for the study of physical chemistry in distinct courses set apart for the purpose. I am a great believer in the inspiration which is obtained from contact with other chemists and feel sure that every chemist who occupies a somewhat isolated position, like the single teacher of the subject in a secondary school, would derive great satisfaction from spending a few weeks in association with other chemists of similar standing, even if rigorous, routine class-work were not pursued. Where a number of high schools are situated within reach of one another, it might be possible to form some sort of club or group for the discussion of elementary chemistry with physico-chemical conceptions in view, under the leadership of someone who had sufficient knowledge and experience in the application of these ideas in teaching general chemistry. Most people can get ideas ten times as fast by intercourse with other people as they can when simply reflecting in their own studies."

NOTE.—Dr. Smith has treated the question of physical chemistry in its relation to secondary school chemistry in a general way in his book on "The Teaching of Chemistry and Physics" (pp. 165-171), which is the book referred to under "4."

From Adjunct Professor MARGARET E. MALTBY, Barnard College, New York City:

"1. I believe physical chemistry should be considered in the first year of the teaching of chemistry.

"It seems to me wholly impracticable to follow *consistently* in our schools the method of development of the race in the science of chemistry. We do not begin with alchemy and use the method of the alchemist and gradually lead the student into the phlogistic theory and let, or rather, *force* him (for it is contrary to all rational thought that he encounters in his daily life at the present time) to think in terms of the phlogistic theory until he is convinced of its futility, and so on through all the vicissitudes through which chemistry has passed. Usually the teacher avails himself at the start of the latest the science has to offer, then he briefly traces the historical development, when it is perfectly patent to the pupil why these earlier theories were outgrown and discarded. If this procedure is followed logically, physical chemistry should be the basis on which the student begins to form his conceptions, for there is no advantage, on the contrary a decided disadvantage, in allowing him to form any conceptions that he must discard in the light of known facts to be studied a little later.

"2. The extent and manner of teaching chemistry on this basis must depend upon the nature of the course. I think chemical reactions

should be explained on this basis, *i. e.*, as reactions between ions, whenever that is the case. The theory of solutions, involving osmotic pressure and resulting methods of determining molecular weight, should certainly be taught; also, if time permits, a certain amount of electrochemistry, the theory of conduction in electrolytes, the theory of the voltaic cell, the explanations of the deposition of metals in electrolytic solutions, also the influence of the mass of the substances taking part in reactions. Not to specify in too much detail, whenever physical chemistry furnishes the best explanation for the phenomenon studied, that explanation should be given.

"3. As to the minimum of knowledge of physical chemistry which the teacher should possess, I can give no sastisfactory answer. In my opinion he should know *vastly* more than he ever expects to impart to his pupils. He must know it well enough in all its bearings to feel at home with physical chemistry conceptions.

"4. In regard to the preparation of the teacher, I think a thorough summer course of lectures and laboratory work would suffice for a secondary school teacher, if supplemented by careful reading of such books as Ostwald's 'Grundlinien der Anorganischen Chemie,' translated, if the original in German is inaccessible; Ostwald's 'Analytical Chemistry,' Walker's 'Introduction to Physical Chemistry,' Nernst's 'Theoretical Chemistry,' LeBlanc or Lüpke's 'Electro-Chemistry,' Biltz (Jones and King's translation) 'Practical Methods for Determining Molecular Weights,' Harry C. Jones's 'Physical Chemistry,' Treadwell's 'Analytical Chemistry.' A. A. Noyes and Blanchard describe some very good lecture experiments in the *Journal of the American Chemical Society,* Vol. XXII, No. 11 (Nov., 1900). The physical chemistry department of nearly all our universities, and some colleges and technical schools, have laboratory as well as lecture courses, and a teacher ought, I think, in a summer course, to get the essential principles and methods of experimenting, provided he has had the preliminary training in physics and chemistry."

From Professor J. Livingston R. Morgan, Columbia University, New York City:

"Too much cannot be said, I think, in favor of using physical chemistry to explain chemical phenomena; in fact, there is no other scientific method. We have found here that students who have been prepared from this standpoint have grasped the subject more completely and do better work later, for the reason, probably, that they have never considered the subject as empirical, but reasoned from facts from the start. Physical chemistry loses much of its value and chemistry much of its scientific character, unless the two are used together even in the most elementary state. This view has long been held in Germany, and now by the translation of Ostwald's 'Anorganische Chemie,' promises to become very prominent here.

"As to the extent of the instruction, the students should understand the elements of the theory of solution, including ionization, osmotic pressure and solubility product, as well as the general law of mass action. The teacher should, of course, go further than this, and should master some one of the non-mathematical text-books on the subject.

"I trust you will not consider that I am speaking only from the standpoint of a physical chemist, for lately I have been in charge of the entrance work here in chemistry and have spent some time in investigating elementary school courses in the subject."

From Professor HARRY C. JONES, Johns Hopkins University, Baltimore, Md.:

"In reference to your first question, the answer is perfectly clear in my own mind. Certain phases of physical chemistry should unquestionably be taken up in the first year's work in chemistry. The important generalizations in physical chemistry which apply to elementary chemistry are, The Theory of Electrolytic Dissociation, The Law of Mass Action, and Faraday's Law, the Basis of Chemical Valence. The Phase Rule, in my opinion should not be touched in the first year's work.

"Of these generalizations, the theory of electrolytic dissociation should be introduced first.

"Valence may be considered, very simply, after chlorine and its compounds with oxygen and hydrogen, while the law of mass action should not be introduced until much later—perhaps not until barium sulphate and its transformation into barium carbonate when heated with sodium carbonate is taken up.

"If these generalizations are not introduced into the first year's work the student learns a great mass of statements about atoms, etc., which have to be *unlearned* before he can advance further in the subject of modern chemistry. We all know how difficult it is to get rid of our first conceptions, and if these are wrong, much valuable time is lost in righting them.

"It may be urged that the conception of an ion is more complex than that of an atom, and should, therefore, be left for a later stage of work. This argument does not appeal to me. If a student can think of an atom, he can certainly think of an atom carrying an electrical charge. In physics the conception of charged bodies is introduced at the very outset in the study of electricity. Further, the fact that the conception of an ion is a little more complex than that of an atom should not enter into consideration, if the former is the real agent in chemical activity. Why teach the chemistry of atoms when we have a chemistry of ions which corresponds to the facts?

"The teacher of elementary inorganic chemistry today should have a good general knowledge of the elements of physical chemistry. This

is absolutely necessary in order that he may see the bearing of physical chemistry on inorganic chemistry. Without this, it is impossible for any one to teach general chemistry in the light of the more recently discovered facts. Such knowledge, if it is not possessed, can be acquired in part from the existing text-books on physical chemistry.

"The time has undoubtedly come when the whole subject of the teaching and study of general chemistry is undergoing a reformation which is radical. The purely descriptive chemistry is giving way to a *science* of chemistry which is the analogue of the science of physics. Great masses of more or less isolated facts are being *correlated* and referred to a few wide-reaching generalizations. In order that the chemist of today, and especially of tomorrow, should be properly trained, it is all essential that he should be started in the right way. Such fundamental work rests in the hands of the teachers in the high schools and colleges."

From C. E. LINEBARGER, editor SCHOOL SCIENCE, Chicago, Ill.:

"1. Yes.

"2. Much physical chemistry or physics is already recognized as an essential part of the course in beginning chemistry. Thus, specific gravity, specific heat (Dulong and Petit's Rule), Avogadro's Hypothesis, etc., are really of physical nature. I presume that the question refers, however, mainly to the Theory of Solutions as developed by van't Hoff and his school, and Arrhenius' Dissociation Theory, and perhaps also to Mass Action and ordinary dissociation phenomena.

"In the Theory of Solutions it is my practice to give a kinetic explanation of osmotic pressure and to call attention to the role it plays in solutions; to bring out the analogy between the gaseous and dissolved states; to show that lowering of freezing point and raising of boiling point is proportional to osmotic pressure, and that measurements of freezing points and boiling points can be utilized in the fixing of molecular weights. This is done without mathematical paraphernalia and as simply as possible. I might state *en passant* that this subject is simple enough in its elements for the comprehension of high school students.

"I make frequent mention throughout my course of the influence of mass in determining the character of the action of certain substances upon one another; I do not give any special account of the matter—simply call the attention of the students to the fact that the relative quantities of reacting substances have a good deal to do with the nature of the reaction. They thus, without much effort, come to take into account the influence of mass in a reaction and are in a very receptive condition for a deeper treatment of the subject in their college course.

"In the same fashion, attention is called to the phenomena of gaseous dissociation, and in the discussion of nitrogen peroxide its dissociation

is considered both experimentally and theoretically. I am not sure that the majority of students get much out of this, but there are always a few who succeed in making it a working possession.

"A somewhat detailed treatment of ionization is given, for it has been my experience that the subject is quite within the powers of high school students. The phenomena of electric conductance are shown by a model and some simple experiments performed in the laboratory. The solubility product is illustrated by a special experiment and the analogy brought out in its discussion with the phenomena of ordinary dissociation as discussed in the case of nitrogen peroxide.

"3. A mastery of the contents of such a book as Holleman's, translated by Cooper and published by John Wiley's Sons, would be a fair way of estimating a minimum of knowledge that a teacher should have.

"4. Walker's book on Physical Chemistry, Jones' perhaps also would help to such an equipment. There are several other books which would also be good. Anyone can easily ascertain what they are. A study of such books ought, however, to be complemented by a laboratory course in physico-chemical methods. Such courses are now offered by several of the summer schools of our larger universities."

From Professor Warren R. Smith, Lewis Institute, Chicago.:

"If you mean, by physical chemistry, general theoretical chemistry, then the teacher of even the most elementary work should keep its principles constantly in mind and should seize every opportunity to point out to his class the relation between the particular fact in hand and the general principle. It is only in this way that he can weld the student's knowledge of the subject into an organic whole and prevent its being a mere collection of facts, more or less disjointed.

"If, on the other hand, you understand physical chemistry to mean the newer and more complex theories of chemistry, such as the phase rule or electrolytic dissociation, then I should say that very little time should be given to them in an elementary class, and that the question as to whether they should be considered at all should depend largely on the amount of time at the teacher's disposal. There are two classes in elementary chemistry in my charge; one of them has two hours per day, the other three. The two-hour class never hears of electrolytic dissociation. The three-hour class takes up the subject in an elementary way in connection with the subjects 'acids, bases and salts' and 'electrolysis.'

"With regard to the third and fourth questions in your letter, I think that every teacher of chemistry should be conversant with at least as much of the subject as is covered in such books as Ostwald's 'Outlines' or Walker's 'Introduction.' I know of no better way to get the knowledge than to study such books, and also the newer books on general chemistry, like Holleman's 'Textbook' or Ostwald's 'Grundlinien', in which the subject is treated from the standpoint of physical chemistry.

From Professor Louis Kahlenberg, University of Wisconsin, Madison, Wis.:

"In his lectures at the University of Chicago, van't Hoff voiced the idea that the advances made by modern physical chemistry lie along the lines of (1) the theory of solutions (being an emphasis of the analogy existing between gases and solutions), and (2) the application of thermodynamics to the investigation of chemical problems. This is a view of physical chemistry which is frequently taken. Now it is clearly evident that the beginner in chemistry does not have the preparation to understand the application of thermodynamics to chemical problems, so that this part of physical chemistry cannot be presented to him. Again, with regard to the theory of solutions and the hypothesis of Arrhenius, which goes with it, it must be said that they are not generally accepted and that later investigations have weakened rather than strengthened these theories. It therefore appears to me that but very little, if any, time should be given in the first year's work in chemistry to the theories just mentioned. The beginner should be made acquainted with the cardinal *facts* concerning chemical change, which should always be placed in the foreground; theories, on the other hand, should, in the first year especially, occupy much less attention, and should be rigidly confined to such views as are quite generally accepted.

"I deem it the province of physical chemistry to investigate the processes of chemical change, especially with regard to the conditions under which such changes occur, and the various energy changes that accompany the transformations. Taking this view of physical chemistry, it seems to me that it would be a mistake to omit to direct the attention of the pupil continually, even in the first year, to the very important influence which temperature, pressure and concentration (mass action) have upon the beginning, the progress and the final outcome of chemical transformations. The concomitant energy changes, such as changes of volume, evolution of light, evolution or absorption of heat, generation of electricity, should be brought to the notice of the student even in the first year. This should be done by means of suitable experiments, and the pupil should be taught that energy changes always accompany chemical action, and that they are quite as important and worthy of study as are the composition and the properties of the substances before and after chemical action has taken place. These facts should be carefully kept before the pupil's mind in the first year. The presentation must necessarily be non-mathematical and rather general in character. To do this properly requires some knowledge of physical chemistry on the part of the teacher. It seems to me highly desirable that a teacher of elementary chemistry be familiar with the salient points of physical chemistry as given in such a work as Ostwald's 'Grundriss', or its equivalent. Teachers who have not had any training in physical chemistry may do much to make up for the deficiency by reading books on the subject, though of course a far better

way is to take a suitable course of lectures, preferably accompanied with some laboratory practice, in some good university."

From Professor H. P. Talbot, Massachusetts Institute of Technology, Boston, Mass.

It seems to me unwise to attempt to teach the principles of modern physical chemistry to pupils of high school age, as a part of the first year of chemical instruction, first, on account of immaturity on the part of a considerable proportion of the scholars; second, because of the present difficulty experienced by the teachers in securing adequate information for their own guidance; and, third, the very considerable time which would be required if the instruction were given in a way to attain any worthy end. There seems to be quite enough material involved in the study of the behavior of the various chemical elements and the fundamental laws governing this behavior to occupy the time, consume the energy and tax the comprehension of the average student during his first year of study. It seems to me, therefore, that this period can best be devoted to work of this character, and that the excursions into physical chemistry should, at most, be limited to a presentation of the electrolytic dissociation hypothesis and a few simple illustrations of its application.

On the other hand, it is obviously a duty of every teacher to acquaint himself with the principles and progress of physical chemistry and to encourage the more able and interested of his pupils to read in this field and to interpret the results of laboratory experimentation in terms of physical chemistry, so far as he finds that the individual can go. It is still true that it is not easy to find detailed information such as will enable the instructor to clearly apply these principles to all, or possibly a majority, of the cases which will arise in the laboratory to his own satisfaction or that of his pupil; yet much may be gained in this direction by reading such works as Ostwald's *Grundlinien der Anorganischen Chemie,* or its translation, Ostwald's Scientific Foundations of Analytical Chemistry, Jones' Elements of Physical Chemistry, and with respect to qualitative analysis, Bottger's *Grundriss der Qualitativen Analyse.* As the results of investigation are gradually incorporated into text and reference books, and, as these books multiply, this difficulty will, no doubt, tend to disappear, and as it disappears the success of the teacher, who cannot devote time to a perplexing search cf original papers for his information, will correspondingly increase, and his efforts will then be restricted essentially by the time at his disposal and the capacity of the students under his charge.

AN EASILY CONSTRUCTED HELIOSTAT.

BY ARTHUR W. GRAY.
Berlin, Germany.

The teacher who has never used a heliostat can hardly realize the disadvantages under which he labors when he employs the ordinary porte-lumiere, or some still more unsatisfactory home-made device, for admitting the sunlight needed in certain optical experiments. The constant shifting of the beam as the altitude of the sun changes is a decided nuisance. This annoyance is generally sufficient to limit the use of sunlight to those cases where it is almost indispensable. When, however, the beam can be thrown in any direction and automatically maintained there with unappreciable shifting for several hours at a time, the field of its usefulness is greatly widened. The applications then extend not only to experiments in optics, but also to demonstrations in all the other divisions of physics, especially where it is desired to show small effects to a large class. For example, the movements of liquids in small tubes, the divergence of the goldleaves of an electroscope, the feeble repulsion between a magnet and a diamagnetic substance, magnetic force lines mapped by iron filings, and a hundred other things, which will at once suggest themselves to the teacher, can be projected on the wall or on the ceiling with considerable magnification. And the application of projection as an aid to instruction is not confined to the subject of physics. There is scarcely a department in the school that cannot profit by an intelligent use of it. But the high prices charged for heliostats prohibit the introduction of such luxuries into any but wealthy institutions. However, one having the mechanical skill that every physics teacher ought to have, can easily make a very effective instrument for three or four dollars and a little labor. How to do this is described in what follows.

Although heliostats of the type employing but one mirror possess certain advantages over those of the two mirror type, the

latter are easier to construct. Accordingly, I made my instrument with two mirrors. For those unfamiliar with the principle upon which a heliostat works a few words of explanation are added.

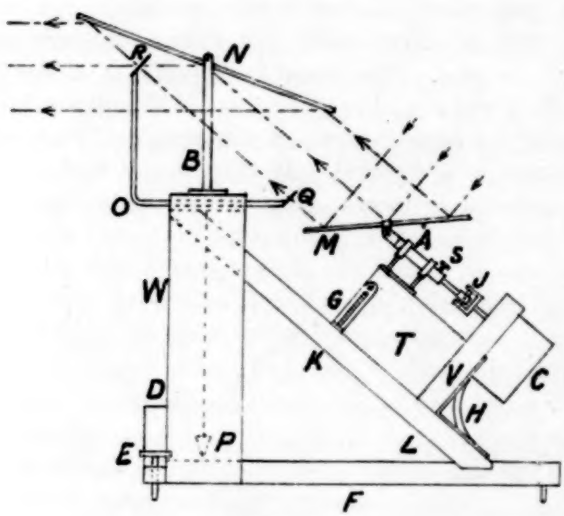


FIG. 1.

A plane mirror M (Fig. 1) rotates about an axis parallel to the axis of the earth, turning uniformly at the rate of one revolution per day in the direction opposite to that in which the earth turns. If now the mirror is once adjusted so that sunlight falling upon it is reflected parallel to the axis of rotation, the reflected beam will maintain this direction, its various elements merely describing cylinders about the axis. This beam can in turn be reflected in any desired direction by means of a second fixed, but adjustable mirror N. The angle that the mirror M makes with its axis will, of course, require slight changing from day to day as the noon altitude of the sun changes with the revolution of the earth in its orbit.

The axis about which M rotates is made from an old bicycle pedal A, which may be had for the asking from the scrap-heap of almost any cyclery. One foot-rest is removed while the other serves as a base for fastening to the main framework. The axle of the pedal is driven by a clock C, costing about seventy-five cents. The most convenient form comes cased in a nickel-plated cylinder about ten centimeters in diameter by six deep, and is usually supplied with an alarm, which, of course, is unnecessary for the present purpose. The main frame-work is made from the stout boards K and F and two uprights like W, all solidly fastened together with the angle L equal to the latitude of the place where the instrument is to be used. At right angles to K and to each other are fastened by means of screws and the brackets G and H, the short boards T and V, which support A and C, respectively. The cross-piece D, fastened to the uprights W and extending some distance on each side, holds the two leveling screws E, which can be made from large wood-screws with the points filed blunt.

As the hour-hand of the clock makes two revolutions daily, the proper speed may be obtained by soldering to the sleeve that turns this hand a small brass gear, and meshing this gear with another of the same pitch but of twice the number of teeth. This, however, will give the rotation in the wrong direction, which necessitates the employment of a third gear similar to either of the other two; but the two like gears must mesh with each other. The hands, dial, and glass should be removed from the clock and the supports necessary for the gears screwed or soldered directly to the frame containing the works. The glass should be replaced by a disk of sheet metal soldered to the inside of the clock case and provided with a hole through which the driving-rod freely projects. A felt washer snugly fitting this rod and covering the opening will aid in excluding dust. The driving-rod should fit neatly but loosely into a hole drilled into one end of the pedal axle and coaxial with it. The set-screw S serves to clamp the pedal axle to the rod from the clock. It is advisable to make a universal joint at J in order to prevent unnecessary friction due to cramping, if all is not very accurately fitted together.

The mirror M should be so attached to the axle of A that

the angle between them is adjustable. N is conveniently swung between the arms of a U-shaped metal yoke B, which is fastened by a single screw to a small board joining the tops of the uprights W. This makes N adjustable about both a vertical and a horizontal axis. The joints should possess sufficient friction to prevent jars from changing the angles. German plate glass is suitable for the mirrors. The width of M should be at least as great as the diameter of the largest lens possessed by the school, and the length should be one and eight-tenths the width, in order that the section of the reflected beam shall in no place be less than the width of the mirror. N should be large enough to receive all of the beam reflected from M at any angle of incidence that is likely to be used. It is not, of course, necessary to have N attached to the main frame-work if some other arrangement is more convenient.

It would be very difficult to adjust A so that its axis is accurately parallel to an edge of K; but this is not necessary. It is, however, essential that the direction of the axis, or of some line parallel to it, should be accurately known. With a little thought the teacher will devise an optical method of determining this direction. When this has been done, the instrument should be carefully leveled until the line determined makes with the horizontal plane an angle equal to that of the latitude of the place; the vertical projection of a parallel to the axis should be accurately marked on the board F; and a metal plate fastened to F should have a mark on it adjusted directly under the point of the plumb-bob P, unless the instrument is provided with some other means of indicating when it is level.

Outside of the window through which the light is to be admitted a stout shelf should be built at a convenient height. On this one must locate a line pointing accurately north and south. By setting the line projected on the base-board F parallel to the line on the shelf and leveling the instrument, the axis of rotation is easily set parallel to that of the earth. All that remains is to have a means of readily setting M so that the beam reflected from it will be parallel to the axis of rotation. This is afforded by the device ROQ, consisting of a right angle made of stiff metal rod, one arm of which passes rather snugly

through a hole in the board to which B is attached and carries at the end a sheet metal square Q, whose edges are about half a centimeter long. The other end carries a somewhat larger piece of sheet metal R, on which are drawn two intersecting lines parallel to the respective diagonals of the square Q, so that the line joining the center of the square and the intersection of the cross will be parallel to the axis of A. When not in use the arm OR can be turned down out of the way, its correct position being again found by turning it up until a strip of metal soldered to OQ is brought against a nail or other stop fastened to the frame-work.

After the heliostat, with the clock going, has been set out of the window and leveled, the device just described is placed in position, the mirror M adjusted until the shadow of Q falls on the cross, and the set-screw S tightened. All shifting of the beam sent into the room must be done with the mirror N. If everything has been accurately adjusted and the clock keeps good time, the center of the bright patch of light formed on the wall opposite the window will remain in the same place for hours. If it does not do this, a study of its movement will generally indicate what to adjust. Once the proper adjustments are obtained, it is well to fix permanently to the shelf a strip of wood following one edge of F, in order to facilitate setting every time the instrument is to be used. When out of use the clock-work should be saved by loosening the screw S, and the plane of M should be set perpendicular to the axis to prevent it from striking against T in case the clock should accidently set it rotating.

For some years past I have believed that a serviceable heliostat could be easily and cheaply constructed, but I did not find time to put my ideas into practice until last spring. Then I constructed one, which on a test turned the mirror day and night for over a week, in spite of considerable friction due to inaccuracies of alignment in the driving rod. No universal joint was inserted at J and the clock, with the mirror M, was placed above the fixed mirror. This latter arrangement avoids the use of one gear wheel but brings the frame-work in the way of the reflected beam if the heliostat is used outside of a south window,

although it does not interfere with its use outside of an east or a west window. The improvements suggested by experience have been incorporated in the design given. To save space unnecessary descriptions of details have been omitted; the intelligent teacher will see how to adapt the construction to the material he has at hand.

GEOGRAPHICAL EXPERIMENTS ON EROSION.

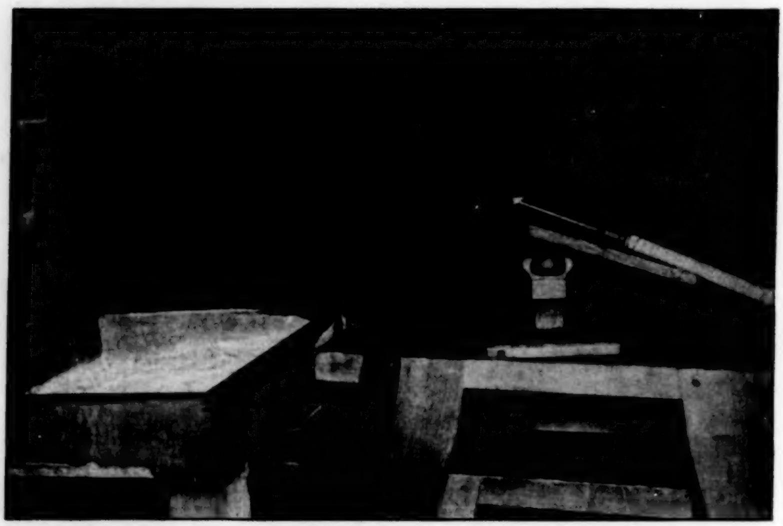
BY WILLIAM H. SNYDER.

The forces of nature are so slow in their action that it is very difficult, particularly for the elementary student, to realize that the surface features of the earth are largely due to the action of disintegration and erosion. If this is really to be pressed home, illustrative experiments showing at least the production of some of these surface forms seem almost a necessity. For some time it has been the effort of the writer to arrange experiments of this kind and at last this effort seems to have met with a fair amount of success. The difficulties are that the results must be accomplished with a considerable amount of quickness and that the forces and the materials used must simulate to a large extent those which are found in nature. If the experiments take too long, interest wanes, and if the forms produced are not distinct and fairly like those found upon the earth's surface, the point of the experiment is lost.

If the right relations between the force of the eroding agent and the material to be eroded can be maintained, then the minute features in the laboratory model can in a small amount of time be made to imitate the gigantic features which have been produced by nature in a great amount of time. Of course with the ordinary material obtainable in the laboratory this approximation is far from close, but such is the fate of experiments in many other branches of science besides physical geography.

Perhaps the most difficult thing to get is a suitable eroding apparatus. The writer has tried many different schemes, but all

of these except one have been unsuccessful. The falling water must be uniformly spread, the drops must be small, there must be little variation at different times in the size of these drops and the amount of water falling on the model must never be sufficient to cause any but the tiniest streams. The apparatus used consists, in the present stage of its development, of two parts, the nozzle and the spreader. The nozzle is a brass tube about a quarter of an inch in diameter made so that it can be screwed to the end of



an ordinary garden hose. The end is then plugged with a piece of brass which has been bored with the smallest size of drill and the end of this hole thinly soldered over and a hole the size of a small cambric needle punched in the solder. The end of the nozzle which screws onto the hose has in it a wire filter in order to keep out all sediments. This nozzle must be made with great care, for it is necessary that a very fine but continuous stream of water shall be maintained. Finally the nozzle must be attached to a pipe where there is a good head of water so that there will be force enough to prevent the small orifice from becoming obstructed.

The spreader consists of a piece of very thin sheet copper about three inches wide and seven inches long, one end of which has been folded over in the form of truncated cone—at the truncated end slightly bent in and roughened with a fine file. This end is then bent up a little, about 30 degrees, and the rest of the strip rounded in so as to form a trough which can carry away the surplus water that escapes from the nozzle.

The nozzle is placed within the spreader so that its stream plays upon the slightly bent-in edge of the cone. The water will arch over in front of the spreader in the form of a very fine mist, which if the spreader is rightly made, will fall uniformly over a surface two or three feet square. The height of the fall and the force of impact can be regulated by the angle at which the end of the spreader is bent up. Some little care will be needed in the adjustment of the nozzle and spreader so as to get the best results, but this is by no means a difficult task. Nothing but a fine mist must be allowed to fall upon the model and this must fall uniformly.

For holding the model the writer has used a rather tight wooden tray one and three-fourths feet square and four inches deep. One side of the tray has holes bored in it at different heights above the bottom. By opening or closing these holes different water levels can be made, thus simulating a rise or fall of the land during the period of erosion. The tray is placed in a slightly inclined position in front of the spreader, the side in which are the holes being the lowest.

To get the best results the materials of which the erosion model is to be made must vary in size and shape of grains, specific gravity, strength of adhesion, solubility and color. As yet not as many different inexpensive materials as desirable have been hit upon for building up the model. A sufficient number, however, for producing the simpler forms have been found. The size of the grains can be determined by using sieves of different sized mesh. The writer uses sieves of 12, 20 and 24 meshes to the inch. The materials are carefully sifted over each other in the tray, the layers being made of the thickness desired and placed in the order desired.

The materials thus far experimented with have been sand, coal

dust, ground brimstone, bone meal, moulders' clay, two sizes of pulverized pumice, chalk and salt. These are named in about the order of difficulty of erosion. Any grain which will not pass through the largest sieve mentioned above cannot be used to advantage.

The brimstone, when properly ground (the writer uses an old hashing machine), is about the best for the erodable hard layer. The bone meal has one great advantage in that, being an organic substance, it can be dyed any color with ordinary aniline dyes. Thus its layers can be made to stand out distinctly. The moulders' clay is very fine but rather tenacious, thus making somewhat subdued relief. The pumice is easily eroded. The salt is the soluble material. All these differ from each other in color and can thus be easily traced in the deposition formations. If the materials are sifted in layers one above the other leaving a vacant space toward the side of the tray in which are the holes and the lower of these holes is plugged, the erosion of plains and the accompanying deposition phenomena can be easily shown. Current action can be produced by causing a small stream to flow from a pipe into the quiet water bordering the model. The action of waves can be simulated by causing a plunger attached to some clockwork or an interested boy to move up and down in this quiet water. In a model produced as above described a geographically inclined friend of mine found nearly thirty characteristic surface features, thus showing plainly its usefulness for illustrative purposes.

Sufficient experiments have not yet been made for determining the best method of showing erosion in folded strata. The method, however, which seems to be most successful is to build up a rough model of the structure which it is desired to imitate and, having covered this with a flexible waterproof cloth and carefully sifted the layers of material onto the cloth, to subject this to the action of the eroding apparatus. The relief cannot, of course, be greatly exaggerated, but this is no disadvantage. Although there is no crushing or breaking of the layers, yet here, as usually in nature, the layers upon the prominences are thinner and therefore more easily eroded than those in the depressions. This is due to the sliding of the material as it falls from the sieve.

Of course the production of the more complex mountain features cannot be simulated.

All, then, that is needed for the illustrative production of a number of the physiographic features of the earth, is the above described simple apparatus, a basement where water can be allowed to run or a sillcock in the school yard, and sufficient water pressure to keep a constant stream. This kind of work can be performed where it is inexpedient to take classes on excursions. Although in many ways it is not as valuable as the excursion, yet in some ways it is more valuable, as here the action is seen in its entirety, whereas in the excursion only the finished product or a phase of the formative action is seen. Photographs taken at different stages in the production of the model are very instructive for reference but the formation of the model itself is the essential thing. The great need is to show the pupils that surface features can be produced in the way in which they are taught that they are produced. Seeing is believing.

HOW TO MAKE A LANTERN SLIDE CAMERA.

BY W. F. WATSON.

Professor of Chemistry and Biology, Furman University.

Lantern slides are easily made by the "contact method" with quite limited appliances. Even the tyro, with the ordinary photographic equipments, can by careful work obtain quite good results. Working in the dark-room, a negative is put into the printing frame and an ordinary lantern-slide dry plate, 3¼x4, is placed upon it in the desired position, with the films in contact. The process is similar to that of making the ordinary print on sensitized paper. When properly adjusted the frame holding the plates is exposed to the light for a suitable time; then the exposed plate is removed and developed like an ordinary negative.

The range of work which can be done by the contact method is necessarily limited. The positive obtained must correspond in size with the negative. Any enlargement or reduction by this method is absolutely impossible. Consequently the operator who has used plates of various sizes for photographic work is fre-

quently annoyed by being unable to make slides from many of his pet negatives. To overcome this difficulty one must have some kind of enlarging and reducing camera. Such cameras are somewhat expensive in these days of trusts and high prices on things photographic. So the photographer who is not expecting to do much work in this line does not feel justified in making the expenditure.

It is possible, however, for anyone having some mechanical skill to construct a lantern-slide camera which will do as good work as the high-priced instruments. An ordinary camera can be used, and, instead of the usual additional extension bellows, two boxes can be prepared, one of them slightly smaller than the other and made to slide easily within it. The directions for constructing a lantern-slide camera of this kind may be stated as follows:

Visit the lumber room of some large retail drug store where their empty boxes are kept. Select two light and well-made boxes, one of which will slide easily within the other and fit in it well. (If boxes of the right kind cannot be obtained, one or both can be made from good half-inch boards.) Both ends should be removed from the larger box and one end from the smaller box. Bore a hole through the remaining end of the smaller box. In this is to be fitted the lens tube of the camera.

Secure a board suitable for a base. This should be about one inch thick and dressed to equal, in width, the base of the larger box. The length should be suited to the requirements and may be determined by experiment, observing the position of the camera when pictures of the proper size are focused upon the ground glass. Nail the larger box firmly to the base, and fit the smaller box within it as shown. The smaller box should telescope within the larger, and slide without any jerky motion. If it binds anywhere, plane it until it works smoothly.

Prepare the open end of the large box for the reception of the negative by fitting in it strips of wood with narrow grooves. After sliding the negative into the grooves the surrounding fittings should prevent all light from entering around the edges of the plate. Paint the inside of the telescoping boxes a dull black. Place the camera on the base and make careful connections between the front end of its lens and the opening in the sliding

box. Be sure that the apparatus is perfectly light-tight, so that no light will enter the lens of the camera except that which comes through the negative.

Take two pieces of thin metal, such as were formerly used for making tintype pictures, and trim them both to the pattern of the camera diaphragms. Make a diaphragm of one of these by cutting a small, round hole through its center. A small opening is better than a large one for this work, as it makes the image sharp and increases the time of exposure, both of which are desirable. The other metal slip may be used in place of a shutter, withdrawing it to make the exposure, and again inserting it when the exposure has been sufficient. Good illumination for this work may be obtained at a north window, supporting the apparatus with the front end elevated so that it will point above the horizon toward the clear sky.

The negatives should be inserted upside down and with the film side facing the camera. If the image on the negative is not vertical but appears somewhat twisted, the fault may be corrected in the lantern-slide which is made from it, by blocking up one edge of the camera with small wooden wedges, until the edges of the picture which is focused upon the ground glass are parallel with the edges of that glass.

Of the two processes for making lantern slides, by contact and with the camera, the latter is generally regarded as the more scientific method.—*The American Inventor.*

The recent discovery of *platinum deposits* on the Gerssena river, at the east side of the Ural mountains, is included in a dispatch from St. Petersburg to the *New York World.* It is said that the deposits are very rich and that, before the government authorities had news of the discovery, hundreds of miners had entered the region and thousands of dollars' worth of the metal had been extracted. Platinum is a metal whose use, for the last twenty years, has enormously increased, while its quantity has steadily diminished.

The news of this "find," therefore, if authenticated, will be most welcome to both the scientific and the commercial world.

Metrology.*

HOW SCIENCE TEACHERS CAN AID METRIC REFORM.

BY RUFUS P. WILLIAMS.

The worker in science uses the metric system. The teacher of physics and chemistry teaches it. The analyst, the microscopist, the electrician and a score of other scientists employ it. With equal truth we may probably say these all believe it to be the best system that has ever been devised, or is ever likely to be, so long as the world adheres to a decimal notation. The grocer, the milk man and the carpenter keep us reminded that there is another system, or an apology for one, crude and of ancient origin though it be. We experience no more and perhaps no less difficulty in paying for a pound of coffee, or a quart of milk, or a dozen eggs, than the uneducated servant girl would the second time she bought half a kilo of meat, or a liter of milk or ten eggs. Liter and quart, half kilo and pound, meter and yard differ but little except in name, and the mind jumps from one to the other and back as readily as the linguist goes from English to French. The metric system has but 12 different words to express the same range of ideas as in the English are expressed by many times that number.

Teachers and workers in science are the ones to whom we in the United States must look for the bulk of instruction in the metric system. In England it is taught in all the schools, but our grammar schools and arithmetics give but little of it. On professional workers, therefore, rests the onus of whatever metric progress is made. For this reason it may be appropriate to consider how such teachers may extend the knowledge and use of the system.

1. Teachers of science order their supplies of dealers in physical, biological, chemical goods. The goods are either imported or domestic. As a large part of glassware and other material comes from Germany or France, it is of course metric. Domestic goods, while quite generally of English measure, are not always so. Deal-

* Communications for the Department of Metrology should be sent Rufus P. Williams, North Cambridge, Mass.

ers in chemicals adhere for the most part to the old system of weights and measures, but at least two companies, Squibb & Sons, and Bausch & Lomb, advertise and sell entirely by the metric, the first beginning to do so in 1892, the second in 1901. Most other firms have some selected goods in metric while the great bulk are not.

The action of medical schools in teaching metric measures and the exclusive use of the latter in the pharmacopæia is forcing druggists to use this system, and surely, though slowly, dealers and manufacturers of drugs will follow.

Teachers can aid in extending this use by ordering all supplies and chemicals in metric terms, never allowing themselves to write or order by English measure, if it is possible to do otherwise. Bottles, test tubes, beakers, etc., should not be ordered by the gross but by the hundred. Diameter of filter papers, capacity of bottles, weight of glass, and volume or weight of all chemicals, should be expressed in the proper metric terms. If every teacher who orders supplies were to do that simple act English designations in dealers' catalogues would soon be a thing of the past. This appears to be the plain duty of every teacher and scientist who believes in helping along the system.

2. The obligations of the teacher of elementary science to his students are scarcely less in metrology than in his particular branch of science. To appreciate the best in science one must learn thoroughly the principles of the best metrology. As the final work in all lines is quantitative measurement, the highest efficiency can only be attained by use of the most accurate tools and the best system. The student then must from the beginning have a comprehensive knowledge of the metric system. The scientific students of today become the teachers, inventors, and managers of great manufacturing interests of tomorrow. If they are thoroughly grounded in the principles of the best metrology, it is absurd to suppose they willingly go back to an inferior system.

While physics and chemistry teachers employ the metric system for the most part, there is usually more or less admixture of English measures and expressions, and textbooks often contain inches, quarts and ounces as well as the metric terms. From the standpoint of the reformer this is excusable only when one is used to

explain the other. The teacher who trains himself to avoid such expressions in lecture room or laboratory and teaches his students so to do has helped the science of metrology, and this statement applies equally to geology, botany, physiology, and the rest. A quarter hour talk on the superiority of the international system and something of its history and growth, will be of value, but a better plan is for the teacher to be in such an attitude towards the system that he will seize every opportunity to say a word in its favor to his students, and to have charts, metric tables and abbreviations, with approximate English equivalents always on view, and some accessible metric literature. All problems should be given in metric terms. In the beginning of any course in science, unless the student has had good training in the system, a series of problems and exercises covering various reductions, including specific gravity, should be given.

3. Many teachers give popular lectures in science or write articles for the press, and such papers are quite apt to be couched in the unscientific nomenclature of old English weights and measures. More than any one else the public needs educating, and here is a good field for the popular writer and speaker. Let him accustom his readers or hearers to the International system, following it by the near English equivalent.

4. The devotee of science may aid metrology by himself becoming familiar with the entire subject of weights, measures, coinage, etc., their origin, development and use in various countries. It is probably true that few chemists or physicists have as clear a notion of the stere or even the kilometer as of similar English denominations. If one finds the history of a subject interesting, this one, which has so much to do with everyday life and is of such ancient origin, will be found particularly so; presently he may find himself noting in every article read the system of measurement employed, and thereby the quality of education of its author.

There were never before so many people interested in the metric system in England and the United States as now, and what is needed is to keep agitating the subject, and promoting discussion through the press. At the very moment when it could be truthfully said that a majority of scientific workers had permanently adopted the system, its ultimate use by the public became

a foregone conclusion. The prime fact is *the metric system is here*, and is used by an increasingly larger number of people every year. Colleges, technological, medical and high schools are turning out tens of thousands of graduates who recognize its superiority. But while the cause was never before so strong as today, every man who believes in it should contribute something of effort to make its progress more rapid.

NOTE.

The Woodman's Handbook, Part I, by Henry Solon Graves, Director of the Yale Forest School, is a recent publication of the Bureau of Forestry, Department of Agriculture, at Washington. It contains chiefly tables and explanations of rules for measuring lumber. Among the multiplicity of measures in those countries that have not adopted the metric system lumber measurement is hardly ever mentioned. And yet here is a field of startling interest to the metricist, for although logs and lumber are generally measured by the board foot, the unit of which is a foot long, a foot wide and an inch thick, yet the methods of measuring and estimation are various and results differ widely. A contemplation of these pages ought to convert every man to a belief in one uniform system, even if not in the metric. The author has tried to collect all the rules for lumber measurement in the United States and Canada. He succeeded in getting forty-three different rules, the elaborate tables and description of which fill more than a hundred pages, the balance of the book containing methods of estimating standing timber, instruments useful to woodsmen, etc. In non-metric European countries the cubic foot is the unit, instead of the board foot as with us. But in most of the states of Europe the cubic meter is the standard measure for logs and lumber. Wood for fuel is measured by the Raummeter, or stacked meter, which is a stack one meter on a side.

In this country the cubic foot is employed in some scientific investigations, but lumbermen will not use it, as they desire a unit which represents directly the sawed product, while the metric system has been used in forestry mainly in investigations on the rates of growth of trees, and even here to a limited extent.

R. P. W.

Notes.

Teachers are requested to send in for publication items in regard to their work, how they have modified this and how they have found a better way of doing that. Such notes cannot but be of interest and value.

PHYSICS.

A Water Trap, to take the place of a bulbed thistle tube, in such experiments as the making of chlorine, hydrochloric acid, ammonia, etc., where the lower end of a straight thistle tube might become clogged up is shown in the accompanying figure.

Bulbed thistle tubes are rather fragile and not always to be had. This substitute is quite as satisfactory and can be made by the pupil himself out of ¼ and ¾-inch tubing and thistle tubes that have become too short for ordinary uses.

E. C. WOODRUFF.

Radium Emission.—It has been discovered that radium maintains itself at a temperature of 1.5° above that of its surroundings. It has not yet been ascertained whether the heat which must be radiated is given off directly as heat from the radio-active substance or is a secondary effect caused by some higher evolution of energy. Sir Oliver Lodge points out that radium emits massive, positively charged particles. which are probably atoms, with a velocity comparable to one-tenth the speed of light. Most of these particles are stopped by a small thickness of air, with the evolution of heat; and if the conditions were such that this heat accumulated, on an average, for one minute before escaping, and assuming the heat capacity of the source and of the surrounding air to be equal to that of one milligram of water, a difference of 1.5° would be set up. This is a plausible explanation of the difference of temperature, but as yet no explanation has been offered to account for the emission of the particles.

BIOLOGY.

The famous Lansing (Kans.) human remains found in a cave and by many competent authorities pronounced to be of glacial age, are, by later interpretations (according to SCIENCE), said to be post glacial.

The germicidal qualities that milk was supposed to possess according to the results of some workers seem to have been based on the presence of a greater number of living bacteria in freshly drawn milk than in milk after a few hours' standing. Subsequent experimenters attribute this to the natural death of many bacteria, simply because they cannot grow in milk, as it is an unsuitable culture medium.—(SCIENCE, March 6.)

The Microcosm of the Drift Line is the subject of an interesting paper by Laetitia M. Snow in the December number of the American Naturalist. The observations upon which the conclusions are based, were made on the southern shore of Lake Michigan during the spring ot 1902. The waves wash up great numbers of land and water insects, many being more northern forms carried here by the southward flow of the current in the lake. These are mostly herbivorous, lady birds, Coleoptera, etc. These stranded forms may revive and depart or may serve as food for predaceous or scavenger forms which are abundant in this locality. Dr. Snow believes that there is a fairly regular order of succession in the arrival and departure of these animals influenced by the temperature, direction and velocity of the wind, season and beach conditions, so that finally this little community of food providers and food obtainers, does not alter the life relations of the beach.

Detroit. CAROLINE HARVEY.

Seed Dispersal.—Last fall some witch-hazel seed capsules were collected and put into 2 per cent formaline. In studying seed distribution a few weeks ago, each student was given a twig bearing a few capsules, with the instruction to pin it up in his room. Some of the students reported a regular bombardment in their rooms about twelve hours after the capsules were put up; the seeds were thrown ten to fifteen feet.

S. O. MAST.

PREPARATIONS FOR DISSECTING PANS.

In view of the fact that such preparations for dissecting pans, as are on the market at present, are either expensive or not very serviceable, or both, it was thought worth while to attempt to work up some mixture that would be more serviceable and less expensive.

An ideal preparation for dissecting pans, it seems to me, should be of such a nature that it will hold the pins. It should be soft enough so as not to crack when bent, adhesive enough to stick to the pans, black enough to form a sharp contrast with delicate tissues, and insoluble in solutions (water, 70% alcohol, and formal) commonly used in dissection.

After considerable experimenting, two preparations were obtained, neither of which prove to be ideal. The formulae of these two preparations (A and B) are as follows:

PREPARATION A.

25 grams of linseed oil.
50 " " coal tar.
200 " " brown resin.
50 " " hard paraffin.

PREPARATION B.

50 grams of coal tar.
100 " " brown resin.
250 " " hard paraffin.

The ingredients of preparation (A) mix most readily if all but the paraffin is first melted and thoroughly mixed, and then the paraffin added and melted and the whole thoroughly stirred. This preparation may be made harder by continuous heating or by decreasing the amount of linseed oil, and softer by increasing the proportion of linseed oil.

As in preparation (A) so in preparation (B), a more thorough mixture is obtained if the coal tar and resin are first well mixed and then the paraffin added, than if all the ingredients are at once melted together. This preparation requires more heating and stirring than preparation (A) in order to cause the ingredients to mix; and at best there will be only a partial mixture. Coal tar and resin being heavier than paraffin tend to collect at the bottom so that in this preparation, it was found best to weigh out the desired amount of substances used, in proper proportion for each pan separately, and melt and mix them in each pan.

As above stated, neither of these preparations is ideal; both lack some essential characteristics. Preparation (A) while insoluble in water and formal is slightly soluble in 60 per cent alcohol, and quite readily soluble in strong solutions and consequently is not satisfactory for dissection in solutions of alcohol stronger than about 50 per cent.

Preparation (B) is practically insoluble in 96 per cent alcohol as well as in formal and water, and is consequently satisfactory for dissection in these solutions; but this preparation does not adhere to the pans as tenaciously as preparation (A), and it might also be improved by being made slightly darker in color.

The amount of either of the preparations required to cover the bottom of a dissecting pan 5x8 inches, about ⅝ inch deep, weighs approximately one-half pound, making the cost of preparation (A) per pan about 4 cents, and of preparation (B) about 7 cents.

Dept. Biol. Science, Hope College, Holland, Mich. S. O. Mast.

Book Reviews.

Descriptive Chemistry.—By Lyman C. Newell. Ph. D. (Johns Hopkins), Instructor in Chemistry, State Normal School, Lowell, Mass. 13x19 cms. 400 pages. D. C. Heath & Co., Boston, 1903

This is a companion volume to the author's "Experimental Chemistry." As its name indicates, it is a descriptive chemistry, almost the entire book consisting of text. An examination of the book shows that Dr. Newell has produced a second book which is characterized by a scientific spirit, a keen conception of what is interesting, a due regard for the old, and

a judicious attitude toward the new. It is not a serious departure from the more recent books covering this field, but it contains several new features. We are glad to notice the introduction of considerable matter concerning the applications of chemistry. In this respect the book is ahead of any thus far produced. A large part of one chapter (Chapter X) is devoted to the relation of electricity to chemistry, and numerous references throughout the book utilize the facts and principles thus introduced. Carborundum, graphite, sodium, caustic soda, aluminium, etc., all receive attention. Considerable space is also given to the more common substances, such as illuminating gas, bleaching powder, acids, soap, steel, paper, and sugar. The subject of atoms and molecules is treated in Chapters VII, IX and XIII, in a simple way, free from dogmatism, and in language which the beginner can understand. We are also glad to notice the timely introduction of bits of history. These scattered allusions are strengthened by a chronological table and a biographical supplement in the Appendix. The latter also contains a brief account of the metric system and of crystals.

A set of about one hundred and fifty simple experiments is placed at the end of the book. These are as clear, precise, and practical as those in the Experimental Chemistry, though simpler. The text may be obtained without the experiments, if teachers wish it.

The book as a whole is a handsome piece of work. The type is clean, and the different sizes set off parts from each other in a manner pleasing to the eye and helpful to the mind. The illustrations are excellent, many are entirely new and some are quite novel, especially those covering the newer electrical processes. Five full page engravings of famous chemists add to the attractiveness of the pages.

Teachers will be glad to examine this book, because it contains so much that is helpful, interesting and teachable. Moreover, it is a book which pupils will be glad to read and study.

C. E L.

Introduction to Botany with Analytical Key and Flora. By WILLIAM CHASE STEVENS, University of Kansas. 12½x19½ cm. viii+436+127 pp. Without Key and Flora viii+436 pp. D. C. Heath & Co. 1902. $1.50.

This book is designed primarily for use in high schools in the Spring semester, although if all the subjects are taught there is material enough for a very full year's work. It begins with seeds and follows the life history of flowering plants; devotes 50 pages to cryptogams; has chapters on ecology, distribution and classification of plants; discusses the herbarium, laboratory equipment, and manipulation; contains a glossary and a Flora.

The mechanical part of the book could have been improved by puting the "Observations" (Laboratory Directions) or their numbers in a different kind of type from the "Discussions" (Text) or the numbering of its paragraphs.

An unfavorable impression is given at the beginning of the book by the wording in some of the laboratory directions on seeds and seedlings. They are written to apply partly to seeds in general while giving the impression that they apply to one seed only. *In too many cases the pupil is told the result or the conclusion of the experiments.*

Growth and movement are taken up at greater length than is usual in high school text books.

The discussion of osmosis and of the plant cell would be too difficult for most high school classes.

The development of the function of reproduction and the homology of floral organs is discussed in a way that may also prove very difficult for the pupil until he has studied cryptogamic botany. The chapters on "Plants of Past Ages" could not be intelligible without a knowledge of geologic ages.

The glossary is unusually good, in that it gives the derivation of all terms and could be used to supplement the text where terminology is lacking—as in the chapters on "Modified Parts" and "Fruits." Fruits are discussed entirely from the standpoint of the dispersal of seeds.

In the chapter on flowers, the eyes and appendages of insects are very carefully described and discussed in their relation to cross pollination.

The life history of plants is completed in the first nine chapters, and following this is a supplementary chapter, which gives directions for the study of twenty-five flowering plants, all but four or five of which blossom only in spring or early summer. Here, also, cross pollination is strongly emphasized.

The study of cryptogams (chapters XI, XII, XIII), although an improvement over some half-year text books which can be used for a year's course, is not treated as satisfactorily as the other subjects in the book.

Plant distribution and the adaptation of plants to their environment is discussed from an evolutionary and ecological standpoint.

The Flora would only be useful to a beginner, as it contains only the commoner flowering plants of spring and early summer.

The directions for drawing (especially in the chapters on seeds and flowers) are excellent. This feature alone would make the book well worth examination by every teacher.

While the book has some imperfections which should be corrected, yet it is certainly usable, and it keeps the activities, development and adaptations of the plant constantly before the mind in a way that is very stimulating.

Eastern High School, Detroit, Mich. EDITH E. PETTEE.

Reports of Meetings.

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS.

The sixteenth meeting was held in Cambridge, Mass., Feb. 28, 1903. After the preliminary business, Mr. R. P. Williams read a paper on "Theory Teaching in Chemistry." The paper was too long to reproduce. The views of Mr. Williams are well expressed in the following extract:

"Laws and theories should not be taught in a bunch, but intermingled with facts and experiments, as there is a demand for them; for example, one cannot go far in chemical theory without a knowledge of valence. To put off a difficult subject like valence till the last part of a course, deprives one of all the months of practice which are necessary for a working knowledge of it. Some teachers object to students using symbols and writing equations early in the course. Were they teaching French instead of chemistry, I can almost imagine them forbidding the use of French words till late in the course. If you want to know what reaction takes place, or the products of an experiment, do you not invariably try to write the equation as the simplest solution? Beginners do the same, if they know aught of chemical theory. As we used to be told, we must be able to dream in Greek before we could know Greek, or as one must think in terms of any language before one can really be familiar with it, so we come to think in chemical symbols and equations. The earlier students acquire this ability, this habit, the better for them. By the mid-year examinations, I would have students as familiar with symbols, equations and valences, as they are with experiments."

Mr. I. O. Palmer of the Newton High School, chairman of the committee on new apparatus, explained a convenient way of obtaining the combining weight of sodium. A small cylindrical piece of brass was bored to a depth of 6 mm., with a drill 5 mm. in diameter, the hole being of such size that a wire of known diameter would fit it. The volume of the hole could then be found. The tube is packed with sodium. With the volume and specific gravity known, the weight can be calculated. Gummed paper placed over the sodium while it is under the cylinder for collecting displaced hydrogen, retards action for a few moments.

Mr. G. A. Cowen of the West Roxbury High School showed the diagram of an electric oven made from an oven such as is used with an oil stove. It contained a row of five 16 candle-power lamps arranged at the bottom, so wired that one or more may be used. A temperature from 50° C. to 120° C. can be obtained. A small oven for individual use was shown, made from a tin pail holding three pints. This was

lined with asbestos, and had a 16 candle-power electric lamp sticking up through the bottom of the pail. A wire shelf above the lamp supported the substance to be dried. This oven had a range of 60° to 120° C. The temperature was regulated by opening or closing holes in the bottom and cover of the pail. The cost is about 40 cents. A device for showing spectra to a class was exhibited. The continuous spectrum is thrown upon a black surface crossed by white lines properly placed. The spectrum is visible only upon the white lines. The illusion is remarkably complete. Credit for this device should be given to Prof. H. P. Talbot of the Massachusetts Institute of Technology.

The committee on current events, through its chairman, Dr. Newell, called attention to (1) the new edition of "Data Concerning Platinum," which can be obtained free from Baker & Co., Newark, N. J.; (2) Census Bulletin No. 210, on Chemicals and Allied Products, which can be obtained free from the Director of the Census, Washington, D. C.; (3) The Perry Pictures of Chemists issued by the Perry Pictures Co., Malden, Mass.; (4) *Electro-Chemical Industry*, a new magazine devoted to electrochemistry, and published in Philadelphia, Pa., City Trust building.

Through the courtesy of Miss Delia M. Stickney, teacher of chemistry in the English High School and Miss Kendrick, teacher of domestic science, dinner was prepared and served by the cooking class connected with the school.

The afternoon session was held at Harvard University. Professor Charles R. Sanger addressed the association on "The German Potash Industry." The paper, which was illustrated by lantern slides, was of unusual interest. An abstract will be printed in an early number of SCHOOL SCIENCE.

Reported by LYMAN C. NEWELL.

CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS—PHYSICS SECTION.

The Section met at 2:30 p. m., Friday, April 10, 1903, in the Auditorium of the Armour Institute of Technology. After some preliminary business, a paper on "Some Observations on the Teaching of Physics" was presented by Mr. A. H. Sage, of the State Normal School at Oshkosh, Wis. (This paper is published in the May number, page 67, of this journal.) After a brief, but spirited, discussion of certain points given in the paper, the Section joined with the Mathematics Section to listen to the report of the committee appointed at the Thanksgiving meeting of the Central Association of Physics Teachers on the correlation of high school courses of physics and mathematics.

The Section met at 11 a. m., Saturday, April 11, when a paper on the "Adjustment of High School Courses in Physics to Meet the Increased Scope of Elementary Physics" was read by Mr. Gilbert H. Random, of Calumet, Mich. In the discussion which followed the following points were brought out:

It was suggested that what the pupils need most of all is intimate personal contact with the things they were studying about. This might be best brought about by a closer correlation of manual training with physics and chemistry.

The question was raised: To what extent are the above courses now correlated?

In reply it was said that the correlation, to a great extent, of these particular subjects was a condition that would take care of itself. While the connection was an indirect one, it was no less real and self-assertive. The danger was in so carrying on the courses in science that the pupils who had had manual training would be at such an advantage as to discourage the efforts of the others. One way to make the courses mutually helpful was to have the manual training pupils at the close of their course manufacture pieces of apparatus for the various laboratories of the school. These exercises could be treated as "thesis work," so to speak, by the manual training department. With that in view and at that stage of the course the things made would very likely be of some value intrinsically.

The objection was made that there was danger of interfering to some extent with the plans of the manual training teacher for unity and consistent progression in his courses if too many demands were made on him for apparatus by the other teachers.

In reply, it was suggested that there might be room for such work in an advanced course in manual training. A great advantage is that if a student has made a fine piece of apparatus, those who follow him and see his work, and are told that it was made by a pupil, will feel more as if they could do something like it, or, at least, understand its working. Likewise, those pupils who had manual training might be in a position to attempt more intricate and involved experiments when they came to take up the sciences, and yet not as part of the required work. The performing of such experiments by certain members of the class might prove an inspiration to the class as a whole.

The question then arose as to the relative importance of certain parts of physics, as to which parts may be safely abridged when the time for the course is too short to cover the whole.

Some thought that the subject of heat was the one most amenable to good laboratory work, and that that part of physics was also of the most practical value, after mechanics.

In reply, it was mentioned that physics was primarily the science of matter and energy; that while the energy aspect of heat was of undoubted value, yet it could not be properly presented in an elementary course in the

laboratory; that the experimental parts of heat now presented in laboratories in high schools had little or no bearing on the things that make physics a science, those experiments being little more than measurements of incidental properties of particular substances with no general meaning; that the energy concepts of physics required a mastery of the general properties of matter in motion, and especially wave motion; that if the subjects of light and electricity are to mean much more than a collection of curious and interesting phenomena, then the pupil must have had wave motion and its accessory phenomena emphasized both in class and laboratory; that sound offers perhaps the richest field in physics for experimental work, either elementary or advanced, and prepares the pupil for heat, light and electricity in the best way; that work in sound did not mean work in music, neither did it require a musical ear.

It was replied that the pupils did not understand sound well enough to appreciate it; that it was not evident that a pupil could see a sound motion better than a heat motion, and that the former was not as easy to teach.

The response was made that the difficulty probably lay with the teacher, who, himself, had not had training in sound; that there were many simple experiments and graphic constructions that were at the same time fundamental and far reaching; that suggestions in that direction were soon to be published in SCHOOL SCIENCE.

It was stated that the things that have the most practical value should have the most attention and that those things came under the heads of heat and electricity; that the speaker was acquainted with two classes of teachers: one that wished to build up a smooth and logical sequence of ideas with little regard for the utility of the subject matter, the whole aim being to develop the mind; the other aimed at the acquiring of the knowledge of things that would be of the greatest practical value in the everyday affairs of life.

It was replied that the previous argument refuted itself; that developing the mind could not be otherwise than the ultimate purpose of the school, informing the mind coming second; that the "utility of the subject matter" was the last thing considered in those courses that seemed to be recognized as the foundation of mental training, Latin, etc.; that even were the facts taught useful, they were invariably forgotten before they were ever required in after life; that the practicality of the facts was one thing and the applicability of the principles another.

A committee, to draw up a list of books suitable for high school libraries in physics, the list to be accompanied by some indication as to the special value of each book, was appointed, consisting of A. H. Sage, C. E. Spicer (Joliet, Ill.) and F. R. Nichols (Chicago).

After a lunch, given by the Armour Institute of Technology, the members of the Section participated in an excursion to the Kimball piano factory and then the McCormick Harvesting Company's works.

ASSOCIATION OF SCIENCE TEACHERS OF INDIANA.

The eighth annual meeting of the Association of Science Teachers of Indiana convened at the Shortridge and Manual Training High Schools of Indianapolis on May 24th and 25th. The following program was presented:

PROGRAM.

FRIDAY, 10:00 A. M., MANUAL TRAINING HIGH SCHOOL.

Inspection of Shops and Laboratories.

10:45 a. m.—Organization.

President's Address, Science and Character—W. A. Fiske, Richmond.

Human Physiology in the High School—A. C. Harris, Bedford.

Physiography in the Laboratory—Miss Belle Hilands, Madison.

FRIDAY, 2:00 P. M., MANUAL TRAINING HIGH SCHOOL.

Plant Physiology—Professor J. C. Arthur, Purdue University.

Nature Study and the Science Teacher—Professor L. J. Rettger, State Normal School.

Some Phases of High School Chemistry.—Geo. A. Abbott, Manual Training High School.

Physical Chemistry—Professor W. M. Blanchard, DePauw University.

FRIDAY, 8:00 P. M., SHORTRIDGE HIGH SCHOOL.

Illustrated Lecture, Plant Adaptations—Professor D. W. Dennis Earlham College.

SATURDAY, 9:00 A. M., SHORTRIDGE HIGH SCHOOL.

Reports of Committees.

Coördination of Science and Mathematics—W. H. Howe, Evansville.

The Study of Heat—A. B. Crowe, Fort Wayne.

Original Experiments, Apparatus, or Methods—Volunteers.

Laboratory Experiments in Sound—L. B. McMullen, Shortridge High School.

The meeting was the best ever held by the association. The attendance was more than double that of last year. The value of the papers presented was genuine and the enthusiasm of the discussion far-reaching. An earnest common sense spirit of investigation was highly predominant; a strong determination showed itself against being deluded into following after strange gods because of their attractive trappings. Indeed the best atmosphere of strong yet progressive conservatism, a tone much needed in all our pedagogy, pervaded the whole meeting.

Mr. A. C. Harris's paper on "Human Physiology" was a very well

balanced presentation of the necessities of the subject. There was no attempt at originality, but rather an effort to trim off the wayward attempts at new methods which have so much of their virtue embodied solely in the notion of originality. Especially was this true in dissection and the study of anatomy. The fact was carved into bas relief that much confusion and misconception arises from the impossible attempts of young high school pupils to intelligently dissect the more complex animals. A sound plea was put forth to make temperance teaching scientific in the true sense of the word; to get away from misrepresentation and subversion of the truth back to actual facts; to lop off the parasites of hobbyism and cant and make temperance the key word of all physiology instead of the watchword of alcoholics and narcotics.

Dr. L. J. Rettger paid some timely criticism to nature study that should be carefully weighed, as it seems to be a means of rescuing a valuable subject from its downward path of relegation to the junk pile of fads. He objected strenuously to the distinctive barriers that some nature study advocates are trying to raise between it and elementary science; he pleaded that the Setonesque romantic, fairy tales of science be left out of nature study.

In the paper on "Coördination of Science and Mathematics", the urgent necessity for reformation in the instruction of mathematics was shown and the greater unity of plan and action between the departments of science and mathematics was suggested as a remedy. A word of warning against such extreme reforms as might endanger the integrity of the departments was firmly urged. An earnest protest was made against the domination of this reform by the professors of pure mathematics in the universities, and a declaration of the ability of the high school instructors to solve this problem most practically for their several localities by themselves.

A discussion of Mr. A. B. Crowe's very able paper on the teaching of heat brought up the much mooted subject of the chronological relation of chemistry and physics in the high school curriculum. It seemed to be the consensus of opinion that it was a very illogical and harmful position to attempt to justify that of having chemistry precede physics.

A series of original experiments and new devices for apparatus were presented headed by Mr. McMullen "On Sound."

The enthusiasm of the meeting crystalized in appointing a committee of propaganda for the purpose of an attempt to secure the consent of the school trustees of the smaller high schools to pay the expenses of their science teachers to the next yearly meeting ot the association.

The following are officers of the next year:

President—N. H. Williams, Indianapolis.
Vice-President—W. T. Cook, Greencastle.
Secretary—W. T. A. Howe, Evansville.
Treasurer—J. F. Thompson, Lafayette.

Reported by W. T. A. Howe.